





# Logging and transport in steep terrain

Report of the Fourth  
FAO/AUSTRIA Training Course  
on Mountain Forest Roads and Harvesting  
Ossiach and Ort, Austria, 30 May to 26 June 1983

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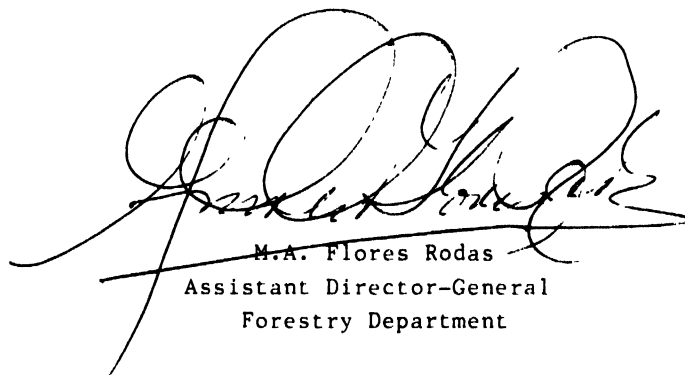
## FOREWORD

A significant portion of the world's forests is located in mountainous areas where, in addition to their traditional role as a source of raw materials, they also have an important protective function. In particular these mountain forests serve to prevent soil erosion, help to maintain the water balance, protect agricultural lands from floods, and provide raw materials for a wide range of forest products. They contribute to the employment of a large sector of society who work in these forests and in its allied industries, thereby enhancing the national economies of many countries.

In order to realize better the multiple economic and social benefits which can be derived from the appropriate utilization of these mountain forests, it is necessary to apply basic principles to the forest operations. It is essential to train foresters in these sound principles, in the proper planning, design, surveying and construction of forest roads, as well as in harvesting operations. This is of particular importance in order to create an environment capable of optimizing the benefits which can be gained from these forests in support of rural development.

Austria, a mountainous country, has developed appropriate logging systems to harvest its forests with due consideration to environmental issues. There exists, therefore, in this report, a wealth of knowledge and practical experience which could benefit foresters from other countries faced with similar harvesting conditions.

FAO greatly appreciates and is very much indebted to Austria for sharing this experience by sponsoring and hosting the Fourth FAO/Austria Training Course on Mountain Forest Roads and Wood Harvesting which was held in Ossiach and Ort, Austria, 30 May to 26 June 1983.



M.A. Flores Rodas  
Assistant Director-General  
Forestry Department

#### EDITORIAL NOTE

The papers presented in this report have been edited to the extent considered necessary for the reader's assistance.

The mention of specific companies or of their products or brand names does not imply any endorsement or recommendation on the part of the Food and Agriculture Organization of the United Nations.

Cover photo: High mountains in Austria where road-building and harvesting are normally carried out with sound ecological principles in mind.

## ABSTRACT

The Fourth FAO/Austria Training Course on Mountain Forest Roads and Harvesting was held in the Forestry Training Centres of Ossiach and Ort, Austria, from 30 May to 26 June, 1983. The course was made possible by a special contribution from Austria in support of FAO's Regular Programme activities in the field of logging. As with the previous courses, this fourth course was organized by FAO in cooperation with the Government of Austria.

The main objectives of the courses were to familiarize the participants with the problems encountered in the harvesting of mountain forests on a sustained basis, taking into consideration the effects of logging on the environment. Particular emphasis was placed on the practical planning, surveying, construction and maintenance of forest roads as well as the planning, choice and use of logging technology suitable for mountain forest conditions.

Other important objectives were to draw the attention of the participants to work safety, health, ergonomics and productivity in logging.

The programme of the training course included lectures, country statements, excursions, demonstrations and practical field exercises.

The training course was attended by 25 participants from the following 15 countries:

Benin, Bhutan, Ethiopia, Honduras, Korea, Malawi, Mexico, Mozambique, Nepal, Panama, Paraguay, Sudan, Tanzania, Turkey and Uganda.

The participants included people from institutions such as ministries of agriculture and forestry, public forestry administrations, public and private forest enterprises and forestry training centres.

This report is a compilation of the lecture papers presented. It is considered to be the most comprehensive one prepared to date since it also contains lectures published in the reports of the previous courses.

It is hoped that many foresters from developing countries can profit from the information contained herein.



Strip clearcut, downhill log transport by cable crane.  
Truck being loaded by hydraulic loader.

(Photo: Federal Forestry Research Institute)

TABLE OF CONTENTS

	<u>Page</u>
FOREWORD	iii
INTRODUCTION	1
INTRODUCTORY SPEECH by Leo R. Letourneau	5
I. GENERAL	
Austria's Cooperation with FAO by Hermann Redl	7
Agriculture and Forestry in Austria by Hermann Redl	9
The Ort Forestry Training Centre and its History by Sigmund Stowasser	15
II. FOREST ROAD PLANNING AND CONSTRUCTION	
General Principles of Planning Forest Road-Nets by Otto Sedlak	17
Forest Road Planning, Location and Construction Techniques on Steep Terrain by Otto Sedlak	37
Forest Road-Net Planning and Wood Harvesting by Rudolf Heinrich	55
Machine Input in Forest Road Construction with Special Emphasis on Rock Blasting in Mountainous Areas by Willibald Blaha	67
Costs and Production in Forest Road Construction by Felix Auböck	71
Road Embankment Stabilization with Biological and Engineering Works for Forest Roads by Rudolf Heinrich	77
Case Studies of Wooden and Concrete Check-Dams in Connexion with Forest Roads by Hubert Hattinger	89
III. LOGGING	
Development of Wood Harvesting Techniques in Austria by Josef Wenzl	109
Logging Techniques in Austria by Anton Trzesniowski	111
Work Organization and Wood Harvesting Methods of the Austrian Federal Forest Enterprise by Winfried Egger	129
Tree Felling in Mountainous Coniferous Forests, Techniques, Production and Costs by Anton Trzesniowski	175
Basic Principles for the Selection of Logging Equipment by Leo R. Letourneau	199
Medium Technology in Wood Harvesting by Rudolf Heinrich	225
Cost Calculations in Logging by Hans Jöbstl	241

	<u>Page</u>
Logging Case Studies by Walter Brabek and Anton Trzesniowski	261
Forestry Economy and Ecology with Special Emphasis on Logging in Mountainous Areas by Otto Sedlak	275
IV. ERGONOMICS AND SAFETY	
Introduction to a Checklist for Ergonomic Evaluation of Forest Machines by Josef Wencel	281
Basic Information on Work Organization, Data Collection, Ergonomics and Safety at Work by Wolf Wenter	303
Telemetric Mobile Computer Unit for Ergonomic Measurements in Forest Work by Josef Wencel	319
ANNEXES	
Annex I - Course Programme	321
Annex II - List of Course Participants	327
Annex III - List of Course Staff, Lecturers and Speakers	329

LIST OF PHOTOGRAPHS

	<u>Page</u>
Strip clearcut, downhill log transport by cable crane. Truck being loaded by hydraulic loader	vi
Chainsaw operator wearing safety clothing, making the undercut	4
The conservation of forests and forest soils has been of prime concern which is reflected by the equipment being applied. The Mini Urus pictured above is one example of appropriate equipment	14
Engineer's case of instruments	34
Well-planned forest road networks allow intensive forestry operations	35
Leykam Log-Line plastic chutes of 5m-long U-shaped sections coupled together and used for gravity transport of timber	36
Survey instruments	43
Heavy-duty tractor engaged in road formation work	53
Surveying a forest road with a clinometer	54
Secondary forest road - truck loaded at log landing	58
A forest area opened up by a combination of forest roads and cable cranes	62
Proper planning, design and construction result in forest access roads which are important links between the public roads and the main forest roads	66
Tractor-mounted rock-drill used in mountain forest road construction	70
Blasted material deposited on a steep slope	75
Electrical chainsaw sharpening equipment	76
Construction of a retaining wall consisting of rock boulders placed into the cut slope by excavator	84
Destroyed retaining wall efficiently replaced by gabions	84
A gully being filled by traxcavator, concrete culvert and supporting roundwood construction laid so as to guarantee natural waterflow	86

	<u>Page</u>
Concrete crib revetment consisting of precast concrete beams	86
A series of check-dams made of roundwood at the top of a scree cone	99
Concrete sediment check-dam	104
Example of a sediment flushing dam	106
Sturdy rock-built check-dam in mountainous terrain in Austria	108
The influences of noise, vibration and exhaust fumes from the use of machinery such as power-saws on the forest worker must be considered. An instructor shows the participants the approach using the dosimeter to measure noise levels of equipment	110
Processor picking up tree-length logs for debranching, debarking, crosscutting and making assortments	126
A compact self-clamping multi-span carriage used in logging, construction or wherever material transport is necessary	128
Suitable felling tools and equipment contribute to increased safety and performance in work	152
Steyr four-wheel-drive tractor with logging trolley being utilized to skid logs to roadside	174
Felling cut in a single pass	182
Proper delimbing is a prerequisite for efficient debarking, easy skidding and better selling opportunities	198
Steyr-Ösa processor 705 at work delimbing and bucking	224
Tractor-attached grapple with a single-drum cable winch	228
Tractor-mounted single-drum winch with logging plate	229
Wheeled tractor with Farmi winch and grapple	230
Farm tractor with bogie used for uphill ground skidding	231
Farm tractor with bogie transporting the load	232
Koller 300 cable system extracting logs uphill to the roadside	233
James Jones trailer Alp cable system extracting logs downhill to the road	233
Unloading shortwood which has been transported	234
Akja sledge winch	235



	<u>Page</u>
Multi KBF lightweight ground skidding winch	235
Radiotir Alpin 1 200	236
Cone-type mechanical wood splitter attached to wheeled tractor	239
Agricultural tractor equipped with K300 cable equipment ready to be shifted to next cable-crane setting	240
Power-saw winch for prebunching individual logs from inaccessible areas	240
Felling tools	248
Portable winch being used to place the Leykam Log-Line plastic chutes used in the gravity transport of timber	260
Tractor equipped for forestry work with heavy-duty tire chains and integrally mounted skidding winch. Note cable mainline and chokers with quick-hitch couplings in foreground	274
Dynapac roller often used for subgrade compaction in properly designed forest roads	280
Audiometer used to detect hearing losses	318
Mobile telemetric computer unit built into VW minibus	320
Adequate bridges to carry the heavy wheel loads found on most forest roads are a necessary part of the forest road system	325
Downhill logging with Tricamat - 3-ton Carriage (skyline, mainline, haulback line and dropline). Drive station is an Urus mobile tower yarder. The carriage is passing an easily erected crossline intermediate support	326



## INTRODUCTION

### 1. BACKGROUND

In many developing countries, the use of improper wood harvesting methods in steep terrain causes forest destruction which leads to severe erosion and downstream flooding, seriously affecting agricultural cultivation as well as urban areas and their water supply in the plains.

Therefore, great attention and priority should be given to the preservation of forests which lie in difficult terrain through the application of proper wood harvesting systems, in order to guarantee their protection and social and productive functions in these zones.

Because of the increase in population and expected higher living standards, experts forecast a considerable increase in wood demand for the future, which will make it necessary for forest operations to be carried out under increasingly difficult terrain conditions, especially through the opening-up of the inaccessible forests by means of forest roads. In many developing countries with high population pressures, forestry in the future will have to be relegated to the less populated areas and to lands unsuitable for other purposes, due to terrain and soil conditions.

In remote areas, forestry can contribute substantially to an improvement of the employment situation for local people through intensive forest management, and therefore contribute to their economic well-being and to the overall development of the country.

In mountainous terrain more labour-intensive extraction methods have to be used than, say, for forest in easy terrain; this of course increases the employment opportunities available. Additional employment opportunities are gained by forest road construction and maintenance, rehabilitation of devastated land, afforestation and tending as well as stream channel and watershed protection measures. Many developing countries with forests in steep terrain are concerned that proper forest operations are carried out in such a manner as to maintain the protective function of the forests as well as provide a continuous yield; they therefore have a deep interest in resolving associated problems.

The high interest in training activities aimed at addressing the above-mentioned problems has been confirmed by the very active response to the participation in the four, already completed, FAO/Austria Training Courses which were held for participants from English speaking developing countries.

Based on the recommendations of the first session of the Committee on Forestry (COFO), which underlined the importance of training related to logging and transport, the Government of Austria generously supported FAO logging training activities by financing the First FAO/Austria Training Course on Forest Roads and Harvesting in Mountainous Forests in June 1975 in Ossiach, Austria.

In line with further recommendations on training and improvement of forest operations made by COFO and the Eighth World Forestry Congress held in Jakarta in October 1978, the series of training courses under a joint FAO/Austria training programme continued. A second course was held in Austria from 3 June to 2 July 1978. The third course was held from 1 to 28 June 1981 and the fourth from 30 May to 26 June 1983, again in Austria.

More than 145 participants mostly from developing countries from all over the world have so far participated in the first four training courses. In connexion with the

training courses, illustrative technical reports were prepared in order that the information supplied during the courses could be made available to a larger forum, especially to foresters from developing countries facing problems in planning, supervising and executing logging activities in mountainous forests. To date some 6 000 copies of the technical reports of the training courses have been distributed throughout the world, mainly upon requests from individuals, organizations and institutions.

This report is mainly a compilation of the lecture papers presented in the last course; however, it also includes papers from previous courses and therefore can be considered as a synthesis of the first four courses.

It is hoped that the information contained in this report, as in the previous ones, will again be found useful and serve as a reference book for specific issues in mountain logging.

## 2. ORGANIZATION AND ADMINISTRATION OF THE TRAINING COURSE

The preparatory work and the organization of the course were carried out in close collaboration between the Forest Logging and Transport Branch of FAO, Rome, the Ministry of Agriculture and Forestry, Vienna, and the Forestry Training Centres at Ossiach and Ort.

The overall coordination was the responsibility of Dr. H. Redl, Head of the International Division, and his colleagues. The administration of the course was carried out by the Verein zur Förderung der Forstlichen Forschung in Österreich, headed by Mr. D. Hanak-Hammerl.

Mr. S. Stowasser and Mr. A. Trzesniowski from Austria, and Dr. R. Heinrich, FAO, Rome, were appointed course directors. In addition to the course directors, more than 30 lecturers, speakers and instructors contributed to the programme. Lecturers from more than 20 different forestry institutions, organizations and machine manufacturers were brought in to support the forestry teachers and instructors of the Forestry Training Centres at Ossiach and Ort.

Administrative, technical and secretarial assistance was provided by 28 people from the Forestry Training Centres and the Federal Forestry Research Institute.

## 3. PURPOSE OF THE COURSE

The main objective of the course was to provide foresters from developing countries with basic information on planning and carrying out mountain forest operations with due regard to environmental protection and conservation aspects. Particular emphasis was placed on planning and surveying of forest road networks as well as harvesting systems. Lectures, discussions and demonstrations also covered such issues as safety and health of forest workers, ergonomics and time and work studies, all of which are considered to be important aspects of the harvesting process, in addition to being a means of assisting decision-makers to analyse relationships between man and work, as well as to evaluate work methods and systems and thus productivity and costs.

## 4. RESULTS AND RECOMMENDATIONS

The training course was opened by Dr. H. Redl, Head of the International Division, Federal Ministry of Agriculture and Forestry, Vienna. Mr. L.R. Letourneau from FAO Forestry Department, Rome, in his introductory address welcomed the participants of

the training course on behalf of the Director-General, Dr. Edouard Saouma, and the Assistant Director-General of the Forestry Department, Dr. M.A. Flores Rodas.

During the first part of the course, besides the classroom instruction, which was kept to a minimum, excursions, demonstrations and field visits were also carried out.

The second part of the training course was carried out in Ort and was concerned mainly with forest road planning, surveying, construction and environmental factors, as well as work organization, safety, health, time and work studies. This part of the programme was again practical and consisted of outdoor demonstrations and field exercises.

During the course participants presented very interesting country statements, introducing brief accounts of forestry in relation to wood harvesting operations.

An evaluation of the course by the participants highlighted the following:

- This type of practical-oriented training course was of great interest to the participants because it introduced a difficult subject by showing and explaining tangible results derived from long experience in wood harvesting operations in Austria.
- The presentation of country reports by the participants and the subsequent exchange of views on wood harvesting in different countries was considered to be a most valuable exercise for which more time should be allocated in future courses.
- More emphasis should also be placed on cost and productivity studies, comparing various alternatives of wood harvesting systems.
- The participants also suggested that intermediate technology in logging is very important for most of their countries and that perhaps more time should be devoted to labour intensive methods or a combination of labour intensive and sophisticated methods with suitable pilot case studies.



Chainsaw operator wearing safety clothing, making the undercut

(Photo: O. Sedlak)

## INTRODUCTORY SPEECH

by

Leo R. Letourneau  
Director, Forest Industries Division  
FAO Forestry Department

On behalf on the Director-General, Dr. Edouard Saouma, and the Forestry Department of FAO, I take pleasure in welcoming you to the Fourth FAO/Austria Training Course on Mountain Forest Roads and Harvesting. Dr. Flores Rodas, Assistant Director-General of the Forestry Department, who had intended to address you today, was suddenly called away to perform other duties and will be unable to be here with you. He sends his regrets and his best wishes for a successful course.

It is a pleasure to see so many foresters from so many areas of the world, who have taken the time and effort to come to this course in order to broaden their knowledge of forestry in general, and logging in particular.

At this time, I would like to extend thanks to our Austrian hosts, for without their generous and unstinting assistance this course would not have been possible. This is the fourth course of its kind, which in itself attests not only to the generosity of Austria, but also to their interest in the subject, in which they are world leaders.

It is only fitting that I mention the close and cordial relations between the Forestry Department of FAO and Austria in this field, especially with Mr. Plattner, Head of the Forest Department, and with Dr. Redl, Chief of the International Division, for through their actions not only are we able to have such courses, but we are also able to rapidly place foresters from developing countries into specialized training courses in Austria.

Now down to the work at hand. You have been selected by your countries to take part in this training course so that, upon your return to your home country, you will have a better idea of how to conduct harvesting operations, not only in steep terrain, but to better understand the ramifications of your actions upon the terrain, forests and streams, as well as the social/cultural effects on the people around you - the workers, villagers and industrial users of logs.

I mentioned above that you have been selected. Perhaps some of you applied for the course out of your keen interest in this field. Logging is a specialized field which is not often taken up as a career by young people from tropical countries. Very often it is looked upon as one phase of a hoped-for long career in forestry or governmental service. No matter what the intention, this course is designed to enlighten and broaden your outlook. A plus factor will have been gained if, in the years to come, many of you are still active in this field.

The logging profession is a difficult one, requiring that one wins his so-called spurs in the jungle. But it is not only an arduous occupation, it is and can be a rewarding one. Rewarding in the sense that one is, through his specialized training, bringing order out of what is sometimes chaos and bridging the gap between the growing of trees and their use.

At this point, it is worthwhile to note that logging is not merely an appendage of some form of primary forest industry. Logging must stand on its own, whether or not it

is part of an integrated project. It must produce a log for further processing which is of first class quality consistent with the original raw material, the tree. It is important that you remember this and do not always accept a back seat to the so-called primary industries. You are the link between the forest and other industries and are essential to the forest industries development process.

You will see by looking at the course programme that, in addition to covering planning, surveying, logging and road construction, such items as safety, ergonomics and environmental protection have been included. The programme is broad, but is designed to give you the overall picture of what is required for efficient harvesting of the forests.

One of the greatest drawbacks to effective harvesting is the lack of experienced personnel who are capable of making operational decisions designed to ensure control of the harvesters and harvesting operations. The bad effects of this lack of expertise not only show up in higher than necessary production costs, but also often result in lower productivity or even sometimes destruction of the forest, as well as having a negative impact upon the environment.

Proper planning and monitoring are essential ingredients if we are to get low costs, protect the forest and the environment and, above all, reap some benefits for the people who live in and around the forests, and for our respective countries through the creation of jobs, and thus income, forest products and the reduction of imports.

Forests, whether natural or man-made, can and usually do play an important role in the economy of your countries and, as such, must be tended with care. Our task as loggers is to create while preserving. In order to do so, we must learn how to apply basic principles, for not only might each application require a slightly different technique, but sometimes may require an entirely new concept appropriate to the circumstances. A logger must be adaptable, imaginative and self-reliant.

Please indulge me and let me close with the wish that what you will learn here will be put to good use and that, through this course, some of you may decide to make logging your life's vocation.



## AUSTRIA'S COOPERATION WITH FAO

by

Hermann Redl

International Division

Federal Ministry of Agriculture and Forestry  
Vienna

### 1. INTRODUCTION

In 1947 Austria became a member of the Food and Agriculture Organization of the United Nations and has actively served on various FAO committees and sub-committees ever since. In particular, the Committees on Commodity Problems and on World Food Security, the worldwide Commission on Agriculture, the worldwide Forestry Commissions and the Committees of the European Region on Agriculture and Forestry should be mentioned. Austria also cooperates with FAO on food standards in the Codex Alimentarius.

Austria attaches the greatest importance to FAO and intends to contribute constructively to its activities in the future as in the past. In this way, Austria will continue to assist in the development of the Third World and in fighting hunger throughout the world.

Cooperation with FAO in Europe - apart from the activities of Codex Alimentarius - concentrates mainly on the European Commission on Agriculture and the European Forestry Commission.

### 2. JOINT PROGRAMMES

Jointly with the United Nations, FAO founded in 1963 the World Food Programme in which Austria has participated from the beginning. In 1983/84, her contribution amounts to US\$6 million. Austria contributes both cash and dairy products to the programme.

A follow-up of the 1974 World Food Conference is the International Emergency Food Reserve, a voluntary reserve established in 1975 by the General Assembly of the United Nations to enable the World Food Programme to react swiftly to a food crisis. Austria has participated in this programme since 1981. In that year the country provided 5 000 tons of grain, and double this amount in both 1982 and 1983. I should also mention that under the Food Aid Convention Austria supplies a further 20 000 tons a year.

Following a request by FAO, the Austrian Federal Government decided on 4 October 1960 to participate in the worldwide campaign against hunger and to establish for this purpose the Austrian FFHC Committee. The objective of this committee is to awaken and increase the interest of all people in the campaign. Since its foundation the Austrian FFHC Committee has carried out projects with a total value of more than 27 million Austrian schillings, a substantial contribution. Austria attributes special importance to the implementation of those projects which are of benefit primarily to rural populations and which help the poorest in the developing countries to help themselves.

Above all, Austria furthers those projects which follow the resolution for the promotion of seed economy, unanimously adopted by the 1974 World Food Conference. Austria is convinced that quality seed is one of the cheapest and most effective means of improving production and that it enables a small country to make a substantial contribution to the international community through the transfer of know-how. Austria looks back on a long internationally acknowledged tradition in this particular sector. In cooperation with FAO, Austria has prepared instruction material for seed preparation which is used in various FAO training programmes throughout the world. Moreover, training courses have been held in southeast Asia, in Latin America, and in Africa. Another training course is presently being prepared.

Finally, I may point out that the Austrian FFHC Committee also grants fellowships to candidates from developing countries, who study at either the University of Agriculture or the Veterinary University in Vienna.

The administrative costs of the Austrian FFHC Committee are totally borne by the Federation, whereas contributions by the Austrian population are without exception used for the implementation of projects.

### 3. AUSTRIA'S COOPERATION WITH FAO IN THE FORESTRY FIELD

Now, to return to Austria's cooperation with FAO in the field of forestry: as mentioned in my opening address, the first training course on mountain forest roads and harvesting was organized in cooperation with FAO in 1975. Others followed in 1978 and 1981.

In close cooperation with the appropriate FAO divisions, training programmes for people from developing countries are currently organized in Austria. In particular, the Forest Training Centres at Ossiach and Ort have made valuable contributions to these programmes. In addition, Austrian foresters have in recent years used their comprehensive knowledge while on consultancies in developing countries.

Last year the meeting of the European Forestry Commission was held in Austria at Innsbruck. It dealt primarily with potential solutions for forest problems in the European region and Austrian activities in this regard were recognized by the election of the head of the Forestry Division as chairman of the commission.

## AGRICULTURE AND FORESTRY IN AUSTRIA

by

Hermann Redl

International Division  
Federal Ministry of Agriculture and Forestry  
Vienna

### 1. INTRODUCTION

Austria, with an area of 83 849 square kilometres and a population of some 7½ million, is a predominantly mountainous country. The greater part of its area (64%) is taken up by the alpine region. The foothills of the Alps and the non-alpine areas are limited to the north and the east.

The total area of the country falls into the following elevation zones:

Below	500	32%
500 to 1 000		31%
1 000 to 2 000		29%
Above	2 000	8%

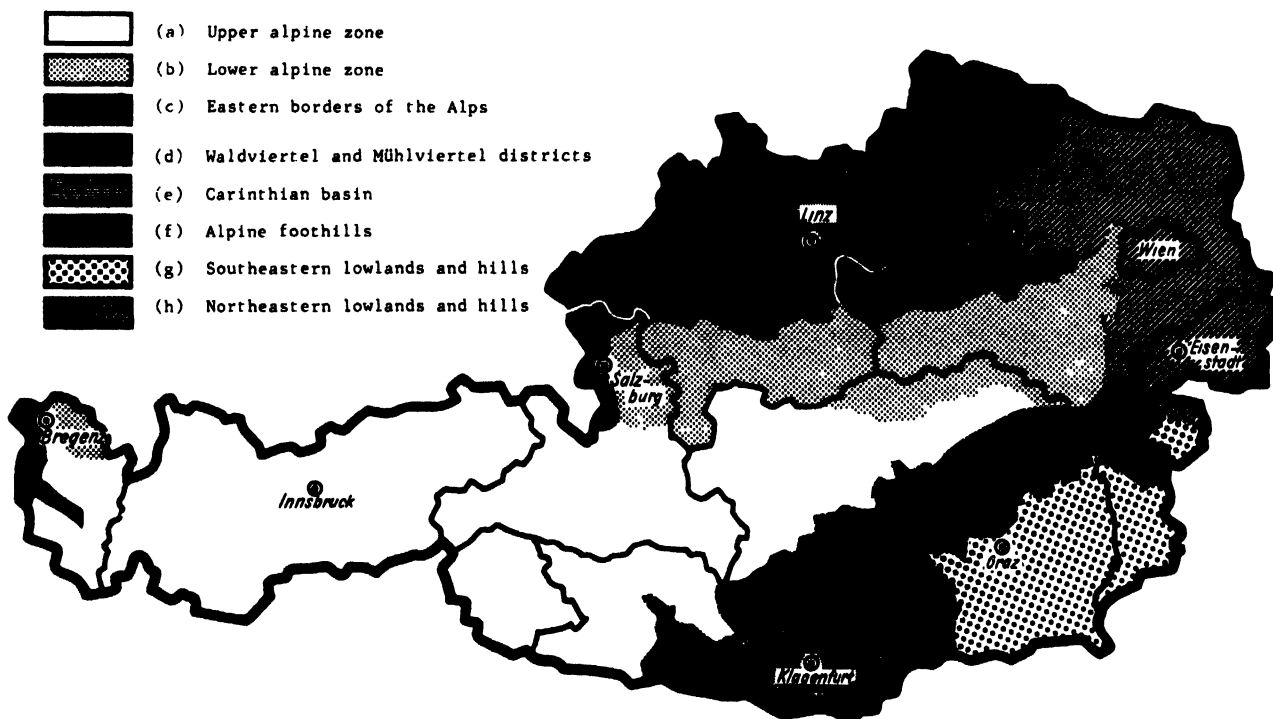
Climatic conditions vary considerably from one area to another, the eastern and northeastern parts of the country being greatly influenced by the Continental Pannonian climate. This is characterized by frosty winters and comparatively limited snowfall and by high summer temperatures. The climate in most of Austria, however, comes within the alpine climatic region, in which the decisive factor for the prevailing conditions is the height above sea level. The average annual rainfall in the low-lying parts to the east amounts to between 500 and 600 mm, reaching over 2 000 mm in certain alpine areas.

The variety of the landscape and climatic zones results in widely varying production conditions, despite the modest total area concerned, for farming and forestry activities. From the point of view of the natural conditions prevailing, the country is subdivided into eight agricultural production zones:

- (a) The upper alpine zone is the largest in area. Highland farming with grassland and farms with a high proportion of forest are typical of this region;
- (b) Lower alpine zone: forestry and cattle husbandry are the main activities of the alpine grassland and grassland-forest farms specific to this region;
- (c) Eastern borders of the Alps: from the climatic point of view this zone occupies an intermediate place between those adjacent to it. The main branches of production are field-grassland and field-grassland-forestry farming;
- (d) Waldviertel and Mühlviertel: the cool moist climate is fairly harsh. The cultivated area is arable land and permanent grassland. The proportion used for forestry differs considerably from one unit to another;
- (e) The Carinthian basin is characterized by a continental climate. The proportion of arable land in the total usable area is about equal to that of permanent grassland;
- (f) Alpine foothills: the mild climate enables this field-grassland zone to be used to a greater extent as arable land. The zone is characterized by a high rate of cattle husbandry and by the emphasis laid on dairy farming;

- (g) Southeastern lowlands and hills: the natural conditions are favourable for production of a wide variety of crops. The small-farm structure of this zone's agricultural system necessitates intensive methods of cultivation (high rate of cattle husbandry, intensive arable farming, special crops);
- (h) Northeastern lowlands and hills: two-thirds to three-quarters of the cultivated area is arable. A high proportion of the arable land is given over to cereals (winter wheat, spring barley). The cultivation of sugar beet is extensive and maize is on the increase. Cattle-keeping, particularly for dairy farming, is decreasing.

THE PRODUCTION ZONES OF AUSTRIA



Source: Report on Position of Austrian Agriculture 1971, Federal Ministry of Agriculture and Forestry

## 2. FORESTRY IN AUSTRIA

Of the 8.4 million hectares in Austria, an area of about 3.7 million hectares are wooded. This proportion of 44% makes Austria the most richly wooded country of Central Europe. The only European countries by which it is surpassed in this respect are Sweden and Finland. In the most densely forested areas the proportion exceeds 70%, and it is only in the eastern part of the country, largely devoted to agriculture, that it falls below 30%. The wooded area is increasing by nearly 2 000 ha annually.

According to Professor Tschermak, Austria may be divided, on the basis of the tree species which grow naturally in the different regions and the climatological differences between one part of the country and another, into seven forest regions. Each of these may be subdivided into two to four altitudinal zones.

### (a) Central Alps

Optimum distribution of spruce, larch and, at the higher elevations, stone pine (Picembra). Maximum elevations: over 3 000 m. The tree line reaches to 2 000 - 2 300 m, the timber line is 200 - 300 m lower. This region is characterized by a continental alpine climate with high daytime amplitudes and a relatively low rate of rainfall, particularly near the bottom of the valleys. The underlying rock is mainly siliceous.

### (b) Alpine intermediate zone

Mixed forest area with fir, spruce and beech. Tree line: approximately 1 800 m. This region has a cool climate with ample rainfall reaching over 2 000 mm. About 50% of the rain occurs during the growth period. The underlying rock is mainly carbonaceous but in some cases schistose.

### (c) Northeastern alpine margin

Similar mixed forests with fir, beech, spruce (decreasing in an easterly direction) and larch (the Vienna Woods variety). Elevations are below 2 000 m, decreasing eastward. Rainfall decreasing, from west to east, to below 900 mm. The northern parts belong to the Flysch zone and the southern parts to the Calcareous Alps.

### (d) Northwestern alpine margin

Optimum distribution of fir and beech, with varying but substantial proportion of spruce. Larch is almost entirely absent. Yew (Taxus) and holly (Ilex) occur in isolated locations. Maximum elevations are over 2 000 m, but trees do not occur above about 1 700 m. Owing to the greater influence of the Atlantic the temperature conditions are moderate with rainfall reaching over 2 400 mm. The underlying rock is generally carbonaceous, particularly in the southern parts of this region.

### (e) Alpine foothills

Situated between the Alpine border and the Bohemian mass, this region is generally characterized by altitudes of 300 - 600 m, although in its eastern part they are usually below 300 m. It is of little importance from the point of view of forestry as it is mostly used for agriculture. Natural tree species are the beech, oak and hornbeam, with some fir. Stands of spruce, pine and larch are cultivated for economic reasons. The average temperature throughout the year reaches 9°C with rainfall ranging from 700 to 1 000 mm.

(f) Mühlviertel and Waldviertel

This region belongs to the southern part of the Bohemian mass, its underlying rock being siliceous. It is an area of mixed forests - spruce, fir and beech, with valuable scots pine in some localities and with oak and hornbeam in the eastern and southern areas. The high plains, between 400 and 1 000 m, have a rather raw climate with a relatively short growing season.

(g) The eastern region

This region, with its warm summers, consists of plains and hills subject to Pannonian (sub-continental) climatic influences. Heights above sea level range between 200 and 400 m. From the forestry point of view this predominantly agrarian and viticultural zone is mainly deciduous, with oak, hornbeam and beech; the few districts with elevations of about 600 m are stocked with mixed beech, fir and pine. Sweet chestnut occurs in the southern part. The rainfall is often below 600 mm, and the average annual temperature is over 10°C.

More than two-thirds of Austria is mountainous. Of the forest area 52 percent is above 900 m and 32 percent even above 1 200 m. In accordance with the country's mountainous character conifers account for 80.4 percent of the forests; 19.6 percent is broad-leaved deciduous trees. The most important tree species, economically, is the spruce, representing 63.5 percent overall and reaching 80 percent in some areas. Spruce is followed by scots pine (8.7 percent), larch (3.8 percent) and fir (3.3 percent). Among the deciduous trees the beech takes first place (9.4 percent). The growing stock of the Austrian forests totals almost 800 million solid m<sup>3</sup>. The production forest areas provide 257 m<sup>3</sup> per ha and thus occupy one of the leading places in the world. The average annual yield per hectare is 6.6 m<sup>3</sup>. The average rate of annual increase in growing stock is about 19 million m<sup>3</sup>. Of this amount about 14 million m<sup>3</sup> is utilized annually.

Much of the forest area is in private ownership. Holdings over 200 ha account for 53.9 percent of the forest land and those over 200 ha account for a further 30.4 percent. The Austrian State owns the remaining 15.7 percent.

Of the total forest area, 76.5 percent is productive forest; 9.0 percent is protection forest with yield; 12.8 percent is protection forest without yield; and 1.7 percent is used for other purposes. The productive forest is mainly high forest (74.2 percent of the overall total) with a small amount of coppice.

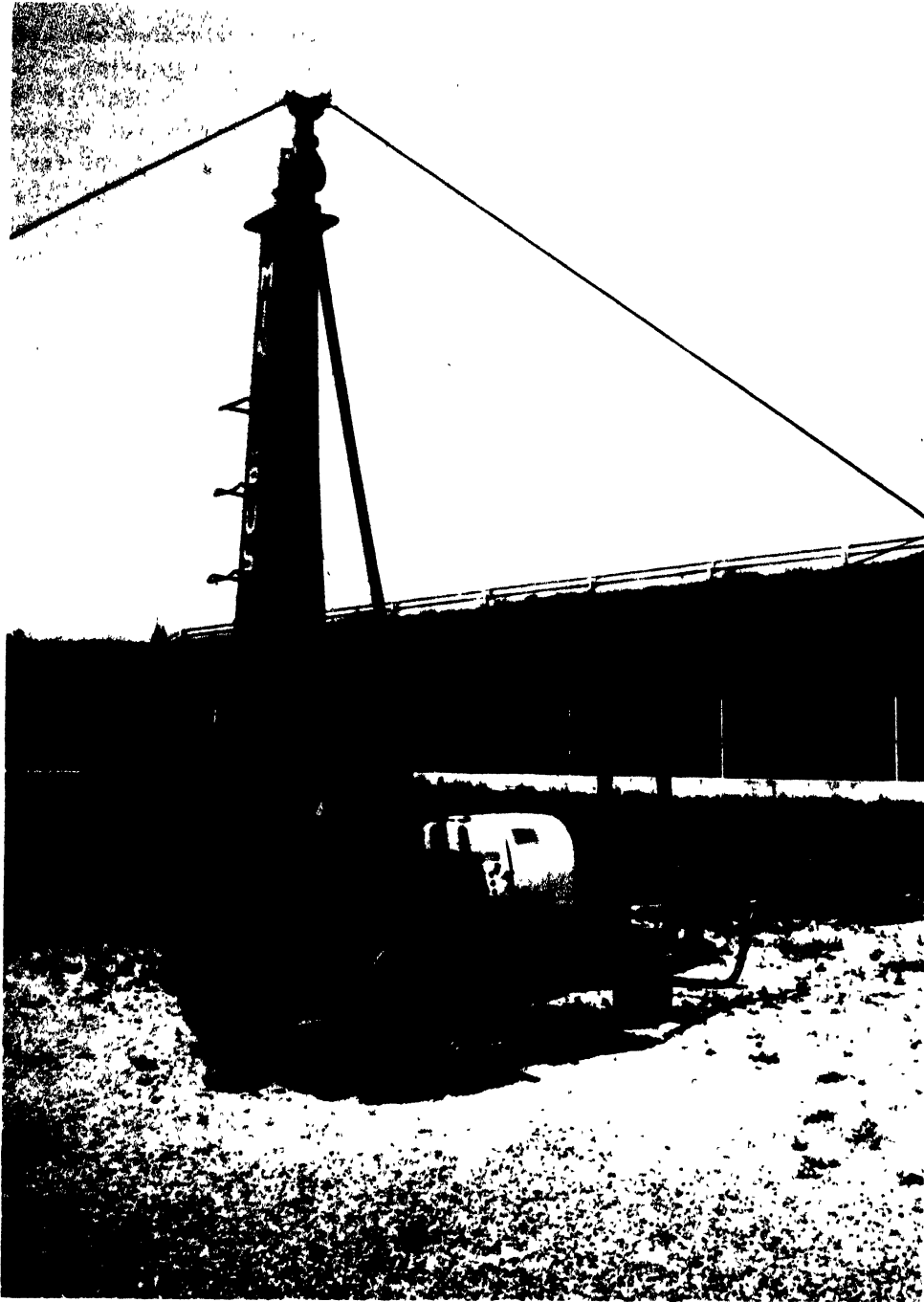
The forest is an important factor in Austria's economy. For almost 250 000 farming concerns it exercises a supportive function. Timber and wooden products make up about 14 percent of Austria's exports. But timber production is not the only important function of the forests. In such a mountainous country, particular attention must be paid to the protection afforded by the forest against avalanches, mountain torrents and landslides. The Forestry Service for Avalanche and Torrent Control, created in 1884, enjoys an excellent reputation internationally.

Because of humanity's increasing need for rest, relaxation, clean air and fresh water, the Austrian countryside, thanks to its beauty and to its wealth of forests, is becoming much more important as a recreation area for people from all over Europe.

The importance of the forest to the country and its inhabitants was already known in much earlier times. Many parts of Austria had conservation regulations 450 years ago. Today a modern Forest Law which came into force in 1975 not only governs all matters relating to forestry but also extends to the interrelationships between forests, industry and society. Some of its main provisions concern the conservation of the forests and forest soils; the utilization of the forests; the limitation of felling areas; compulsory reafforestation; the control of particularly sensitive locations; forestry personnel and their training; the protection of forests; the promotion of forestry (subsidies for improvement, reafforestation, forest roads, etc.); and forest research.

Particular attention is paid to the renewal of stands. About 30 000 ha are renewed annually. About 82 percent, amounting to approximately 25 000 ha, is regenerated artificially, while 18 - 20 percent is regenerated naturally. For reafforestation, about 90 million seedlings are required every year, 75 million of these being spruce. These are planted out as four-to five-year transplants (2/2 or 2/3) which measure 30 - 50 cm and over (or about 20 - 40 cm on the higher mountain locations). About 3 500 are planted per hectare. The seedlings are cultivated in 690 forest nurseries with a total area of 820 ha. The approximate total annual forest seed demand is: spruce 2 800 kg; larch 300 - 500 kg; fir 500 - 800 kg; pine 200 - 300 kg; Douglas fir 150 kg; stone pine 2 000 kg; beech, common oak and sessile oak 1 000 kg each. The regulations provide that for the important tree species only officially approved seeds and plants may be used. The harvest from selected stands takes place after inspection by the Federal Forest Research Station which also keeps a central register. The collecting and processing of the cones and storing of the seed are carried out at special plants (four privately owned and one state-owned seed extractories), while the seedlings are cultivated in nurseries under the supervision of the local forestry offices. For many years control samples have been taken from every harvest in Austria, in order to monitor the quantities of seed produced. In addition, in the case of the spruce, a series of early tests is performed in order to ascertain the seed characteristics. This enables the seed for this tree species to be sent to the most suitable area, as regards elevation and recommended utilization. In 1979, about 27 600 ha of selected seed stands had been registered (70 percent for spruce). The register is now under revision to permit listing of the total harvestable stands.

The Austrian regulations concerning seeds and plants for forestry purposes are in accordance with the rules of the international OECD control scheme for forest reproductive material, a scheme in which Austria has participated since 1969.



The conservation of forests and forest soils has been of prime concern which is reflected by the equipment being applied. The Mini Urus pictured above is one such example of appropriate equipment.

(Photo: R. Heinrich)



## THE ORT FORESTRY TRAINING CENTRE AND ITS HISTORY

by

Sigmund Stowasser

Director of the Forestry Training Centre, Ort

In my capacity as head of the Forestry Training Centre at Ort as well as on behalf of my colleagues, I would like to take this opportunity to welcome you here today. It is our hope that during the 14 days of your stay here you will acquire a great deal of forestry knowledge and skills which you can take home with you and apply to your own situation.

I would now like to give you a brief history of this building, called the Landschloss of Ort, as well as a description of the activities of the Forestry Training Centre which it houses. The Landschloss dates back to the time of the Peasants' Wars. The castle on the lake, or Seeschloss, had already been built around 1020 A.D. on the site of a Roman watchtower. Around 1627, Adam Count Herbersdorff, who defeated the peasants in the Battle of Pinsdorf, made them build the Landschloss of Ort on the site where the farm buildings belonging to the Seeschloss had been before they were burnt down.

Following Count Herbersdorff's death in 1629, the castle changed hands several times. Between 1880 and 1890, the building underwent extensive renovations and reconstruction: the onion domes were added to the towers, the ground-floor sections were expanded, and stables were constructed at the rear. Certain building elements were taken from castles in the surrounding area, particularly from Schloss Scharnstein, such as the doors of the banquet hall, the fireplace, the ceiling frescoes, the wood panelling of the walls, the wood ceilings and various antique doors and stoves. Another addition at this time was the well-head in the courtyard, which is thought to have originated from the fortress at Komorn. One of the most striking features is the representation of the coats of arms of the former castle owners on one of the courtyard walls. The canvas oil painting on the ceiling of the banquet hall is a portrayal of Pallas Athena introducing painting into the circle of the seven free arts.

In 1914, the Landschloss was purchased by the Kaiser Franz Josef Jugendheim Foundation, St. Hubertus. During the first world war the building was used as a military hospital and for a short time as a boarding school. In 1919 the Hubertus Foundation offered the building as a home for the Forestry School at Ort in place of its schools in Hall and Gusswerk.

The present school was opened on 1 October 1919. Its location at Ort was particularly advantageous since a forestry and domaine administrative office had already been established in Gmunden. In 1926, the Federal Ministry of Agriculture and Forestry took over the school, which at that time offered a one-year training programme. In 1934, the programme was expanded to a two-year course.

The school continued to run during the second world war from 1938 to 1945. At the end of the war the Landschloss was taken over by the American occupying forces, and it was not until October 1946 that forestry courses were again resumed.

Moving the training centre from Steinkogel to Ort laid the foundation for the present-day Forestry Training Centre. The school was also assigned the task of training forestry workers and testing new tools, devices and machines. At the same time, continuous training of forestry personnel was carried out in nearly all fields of forest management.

When the Forestry School closed its doors in 1969, the remaining training centre was given the task of meeting the demands of the rapid developments in forestry and forest working techniques and of developing an exact plan for a diversified curriculum. This, and the resulting need for more space, meant that the castle had to be enlarged, and led to renovations from 1968-1970. Expansion and reconstruction of the auxiliary buildings are currently under way.

Thanks to its excellent staff of well-trained experts, the Forestry Training Centre at Ort can now offer a wide range of courses covering almost all areas of forestry: courses for rural youth; training for skilled forestry workers, from apprentices and foresters all the way to forest managers; courses geared to the specific needs of mountain farmers; courses on tool maintenance and power-saws for beginners and advanced students; courses on modern working techniques for small and large timber; courses on setting up cable logging systems and planning of cable logging machinery as well as courses on cable splicing and winch operation; log-line seminars as well as seminars on tree marking for selective cutting and thinning operations; work organization courses for forest managers, forest technicians and workshop managers; management seminars; accident prevention courses which award first-aid certificates; courses on silviculture and forest protection; seed collection and genetics courses; and, finally, blasting courses with special instruction in deep hole drilling and large-scale blasting.

A number of courses are offered outside of the school itself, such as power-saw counselling services at the District Chambers of Agriculture throughout all of Upper Austria as well as engineering courses at various agricultural schools and higher-level agricultural training institutes. Other integral parts of the programme include demonstrations and the organization of excursions for foreign delegations as well as for the Food and Agriculture Organization of the United Nations.

Whenever course activities do not require the participation of the entire teaching staff, some of the teachers work on testing new tools, devices and machines as well as developing new working methods using time-schedules and cost calculations and for the purpose of continued individual training. One of the essential aims of the activities at the Ort Training Centre is to keep abreast of the latest technical developments in all related areas, to eliminate whatever has become obsolete and to integrate new advances into the programme of courses.

To ensure profitable operation of the boarding-school, accommodation is offered in all non-forestry institutions in times when no courses are being held and whenever there is sufficient space.

I hope this has given you an insight into the history of the Landschloss of Ort and into the activities of the Forestry Training Centre. In conclusion, I would like to wish you all a most pleasant stay.

## GENERAL PRINCIPLES OF PLANNING FOREST ROAD NETS

by

Otto Sedlak

Logging Division, Forest Service of Upper Austria

### 1. INTRODUCTION

Forest roads have become the basis of forest management and logging throughout the world. Since roads are the permanent elements in a modern forest transportation system, careful planning is required.

Wide differences in local conditions preclude common specifications for road spacing and road standards. Therefore, this chapter will attempt to explain terms and to describe reconnaissance procedures in general.

The forest road network is planned with the intended or desired skidding method in mind in order to develop a transportation system with minimum overall cost. The requirements of multiple-use management of forest resources and environmental protection are also taken into consideration in the plans.

The basic principle to be followed is: plan from the general to the particular. Therefore, the overall planning of forest development roads constitutes the framework for the detailed project.

A general plan for a forest transportation system including the forest road net is normally drawn up only for large areas. The minimum size for intensively managed forests in the mountains of central Europe is about 300 to 500 hectares.

There is no other field in forestry where mistakes are as irreversible and permanent as in the planning of forest roads. Therefore, variants of the feasible routes have to be investigated on the ground by qualified and experienced personnel. Close cooperation with the local staff who are familiar with the requirements of the specific forest area is indispensable.

### 2. DEFINITION OF TERMS

#### 2.1 External and internal development

Access roads connect a forest area with the public road network, thus opening up the forest area from outside. These roads are normally situated in non-forested land and connect control points along the shortest distance. In Europe, most of these access roads are already constructed and are public roads.

The main function of the forest road net is to develop the forest area internally.

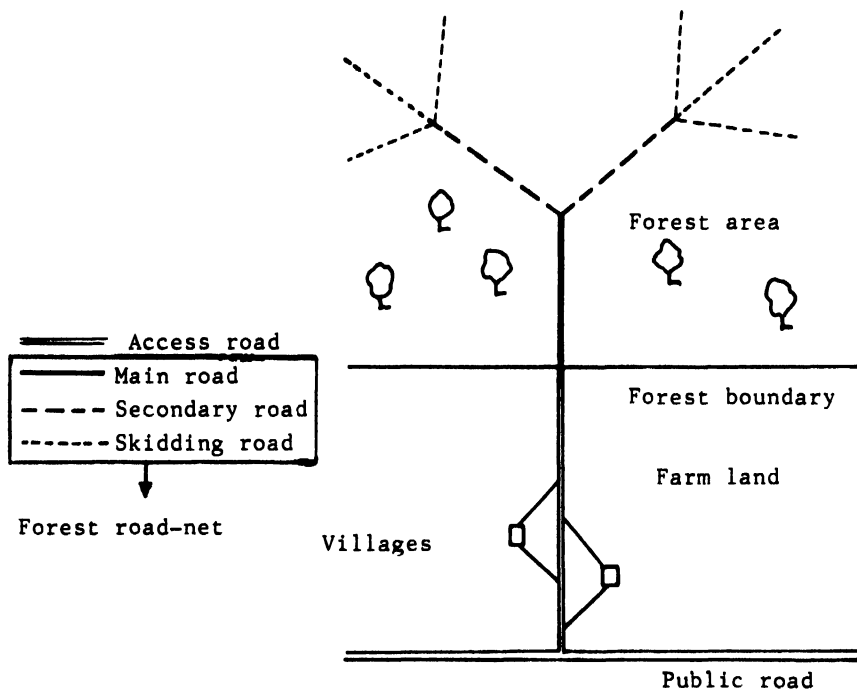


Fig. 1 SCHEME OF FOREST ROAD DEVELOPMENT

## 2.2 Road standards

### 'A' roads (access roads and main forest roads)

These roads are developed for both access and development. They have a relatively high standard of construction and are usable by trucks on a year-round basis. In Europe they are usually single lane, while in tropical areas two lanes are frequent. Bituminous surfaced roads are used only for a high traffic density.

### 'B' roads (subsidiary or secondary roads, feeder roads)

They subdivide the forest into individual logging sections and connect the landings and the main roads. They have a simpler standard of construction and are usable by trucks only in favourable weather conditions.

### 'C' roads (skidding roads)

These roads provide a connexion between the felling sites and the landings. They have no surfacing and are tracks for skidding machines.

EXAMPLE OF FOREST ROAD CLASSIFICATION IN AUSTRIA

Specification	Type of forest road		
	Main road A	Subsidiary road B	Skidding road C
Width of formation b (m)	5.0 - 5.5	4.5 - 5.0	3.0 - 4.0
Width of carriage-way f (m)	3.5 - 4.0	3.0 - 3.5	-
Maximum gradient $g_{\max}$ (%)	9	10 (12)	12 (16)
Minimum gradient $g_{\min}$ (%)	2 - 3	2 - 3	3 - 4
Maximum gradient in adverse direction $g'$ (%)	6	8	10
Maximum wheel pressure P (t)	5 (7)	5 (7)	1 (1.5)

EXAMPLE OF FOREST ROAD CLASSIFICATION IN TROPICAL HIGH FORESTS

(Heinrich 1975)

Road	Road use	Road width: carriage-way including shoulders in m <sup>1/</sup>	Width of carriage- way in m <sup>1/</sup>	Min. curve radius in m	Max. gradient in %	Truck loads per day	Traffic speed in km per hour	Cost estimate in US\$ per m of road
Access road	Pick-up truck, permanent	9-12	7-10	50	6 (8) <sup>2/</sup>	More than 50	50-60	10-15
Main forest road	Pick-up truck, permanent	8-10	6-8	30	8(10) <sup>2/</sup>	Up to 50	25-40	7-10
Secondary forest road	Pick-up truck, temporary	6-8	5-6	20	10(12) <sup>3/</sup>	Up to 6	15-25	1-7
Skidding road	Wheeled skidder, wheeled tractor, crawler tractor		3.5-4.5					0.3-1.0
Skidding trail	Crawler tractor		3.5-4.5					0.05-0.10

<sup>1/</sup> In steep and difficult terrain the road widths given above have to be reduced considerably.

<sup>2/</sup> Maximum gradient in steep, difficult terrain for unloaded trucks when driving uphill.

<sup>3/</sup> Maximum gradient in steep, difficult terrain for a short distance.

### 2.3 Road spacing, road density and skidding distance

Road spacing (RS) is the average horizontal distance in metres between the roads of a forest road network (disregarding skidding roads).

Road density (RD) is the average road length per hectare (m/ha) of a forest road network.

Both terms are defined by means of simple formulae:

$$RS (m) = \frac{10\ 000}{RD} \quad \text{and} \quad RD (m/ha) = \frac{10\ 000}{RS}$$

Skidding distance(s) is the mean value of the theoretical skidding distance, depending on road spacing, topography and the skidding techniques applied. It does not correspond to the actual mean skidding distance in practice. The correlation of road density and skidding distance can be estimated by means of factors of "road efficiency" (Segebaden - FAO).

$$s (km) = \frac{a}{RD (m/ha)}$$

s = average skidding distance (km)

a = road efficiency factor: normally between 5 and 9

4-5 for flat terrain

5-7 for hilly terrain

7-9 for steep terrain

9 and above for very steep, irregular terrain.

Similar studies have been carried out in Germany (Löffler-Timminger, 1977) and Switzerland (Abegg, 1978). The mean skidding distance in hilly skidder country can be determined by the formula:

$$s_{(m)} = \frac{1.8 \times 2\ 500}{RD}$$

This equation is based on a "road-efficiency factor" of 4.5.

### 2.4 Optimum forest road density

The forest road net is the basic component of the logging system. Many variables influence its general layout: size of the logging area, terrain characteristics, climate, timber and growing stock, labour force, equipment, and skidding methods, to name just a few.

The planner's main objective is to find the most feasible and economic system with lowest costs in the long run. In addition to the interdependent costs for off-road and on-road transportation, the non-monetary values of multiple-use management and environmental protection must be considered.

Numerous methods of approximation have been developed for this purpose. Analytical methods, cost-effectiveness analysis and/or computer simulation are of interest in this context.

Analytical procedures are applied mainly to compare transport costs. The major factors for comparison are:

- average annual quantity of timber harvested per hectare
- average skidding cost per hectare
- average road cost per hectare (including construction and maintenance).

Figure 2 shows the general relationship between road cost, skidding cost and total cost.

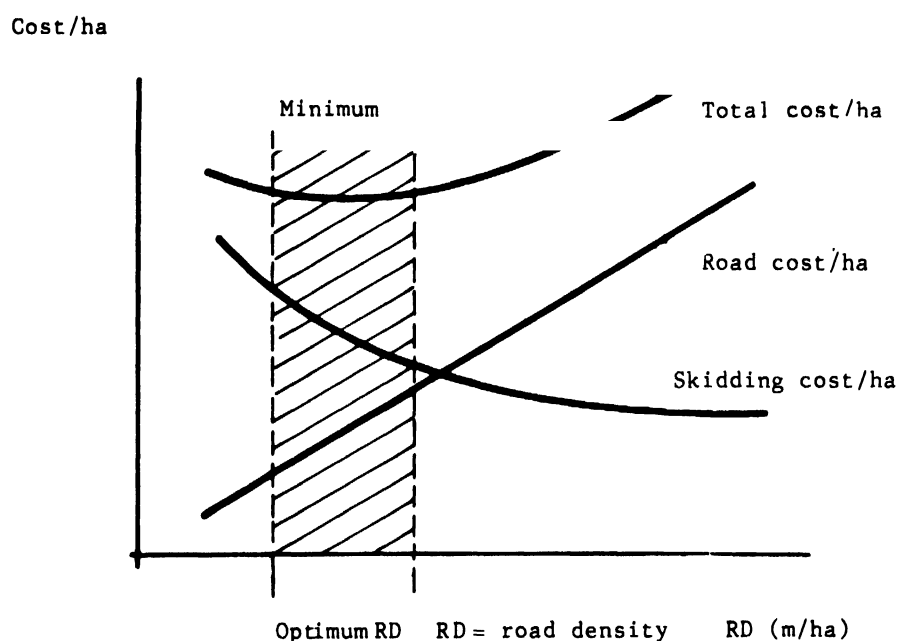


Fig. 2 FINDING THE OPTIMUM TOTAL TRANSPORT COST

Koenig (1970) calculated theoretical optimum values for road spacing in skidder country in Nordrhein-Westfalen of the Federal Republic of Germany by means of an analytical study:

Annual road costs	Annual increment of timber			
	(Low) 3 m <sup>3</sup> /ha		(High) 9 m <sup>3</sup> /ha	
	Flat terrain	Hills	Flat terrain	Hills
Low	700 m	450 m	400 m	250 m
Medium	1 000 m	600 m	550 m	350 m
High	1 000 m	750 m	700 m	450 m



The study by Abegg (1978) to include additional cost-parameters is noteworthy. For hilly terrain in Switzerland road densities of 35 to 60 m/ha, with road costs between US\$50 and 130/m, were recommended.

Assuming an average increment and average construction cost, an example of empirical recommendations for road spacing in Austria, by the author, is given below:

Gradient	Terrain	Skidding	Large forest (> 2 000 ha)	Medium-sized forest (200-2 000 ha)	Small forest (< 200 ha)
0-15%	Flat terrain	Wheeled skidder, uphill and downhill	500-600 m	400-500 m	300-400 m
15-30%	Hills	Wheeled skidder, downhill	500 m	300-400 m	300 m
30-60%	Hills and mountains	Wheeled skidder on skidding tracks, uphill yarding downhill skidding by gravity	300-400 m	300 m	200-250 m
> 60%	Steep terrain	Yarding downhill skidding by gravity	400 m	300-400 m	300 m

A comparison of the truck road densities for commercial forest land in Austria (Austrian Forest Inventory) is of interest. The public road network within the forest (except for highways) is included in these figures. The proximity of the small private forests to the public road network largely explains their relatively high road density.

Type of ownership	Road density m/ha
Small private forests	38
Medium-and large-sized private forests	31
State forests	27

## 2.5 Logging area and skidding directions

The overall design of the road net usually covers a logging area for which the forest transport system is to be developed. One of the first steps in reconnaissance is to fix the boundaries of this area. This is relatively simple in mountainous terrain where the watersheds are marked by ridges. In flat or hilly terrain it is more difficult because the natural boundaries are less pronounced.

The forest road net should be developed in such a way as to take full advantage of the force of gravity for transportation. This is important in view of the rising cost of fuel. In some regions cable logging has resulted in extended ridge road systems since yarding is easier uphill than downhill. But unless the terrain is extremely difficult the forest road net should be developed from the lowest points of the logging area. The main roads should open up the valleys and the slopes should be subdivided into sections by feeder roads, beginning in the valleys. If such a road system is constructed, skidding downhill as well as uphill is feasible. A forest road system which is based mainly on ridge roads and uphill skidding is not the best solution in the long run.

## 2.6 Slope grades and classification of terrain

Slope grade	Classification of terrain	Construction conditions
0 - 30%	Flat and hilly	Simple road construction, few rocks or none, only minor damage to the environment
30 - 60%	Medium hilly and mountainous	
60 - 80%	Steep	Difficult road construction. With rising slope grade more rocks and damage; if the average gradient exceeds 70%, the question should be asked whether road construction is really feasible
> 80%	Very steep	

## 2.7 Systems of forest development roads

Forest road networks have as much diversity as the terrain itself. Nevertheless, there are some typical patterns and designs.

### 2.7.1 Flat terrain

The spacing of a road system in flat terrain can be kept fairly constant. Therefore, practical results correspond to theoretical models fairly well.

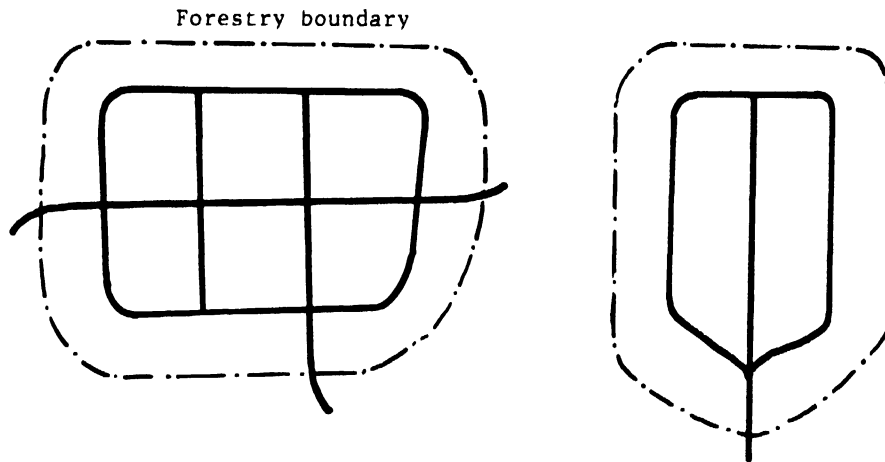


Fig. 3 TWO SCHEMES FOR ROAD NETS IN FLAT TERRAIN

2.7.2 Hilly and mountainous terrain

(i) Valley roads

These are usually the basic main roads for the bottom of the valley and the slopes. Bridges should be reduced to a minimum because they are costly to construct and to maintain.

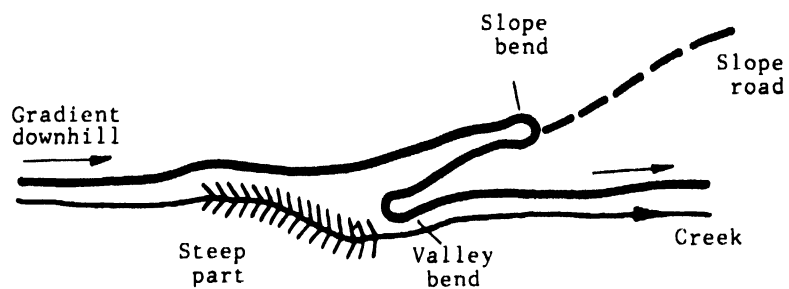


Fig. 4 VALLEY ROAD IN A STEEP AREA (SERPENTINE)

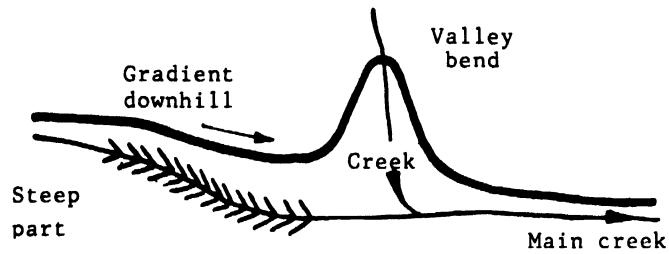


Fig. 5 VALLEY ROAD IN A STEEP AREA (CURVE IN A SIDE VALLEY)

(ii) Slope roads

These start from valley roads and subdivide slopes. A distinction can be made between serpentine and diagonal systems depending on the slope grade.

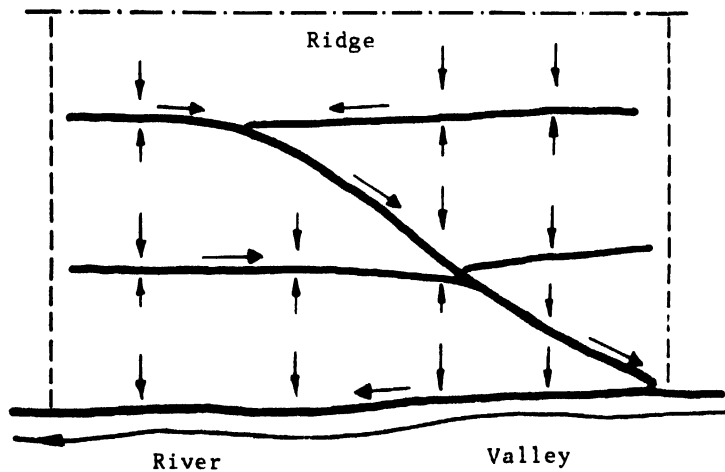


Fig. 6 DIAGONAL SYSTEM ON GENTLE SLOPES

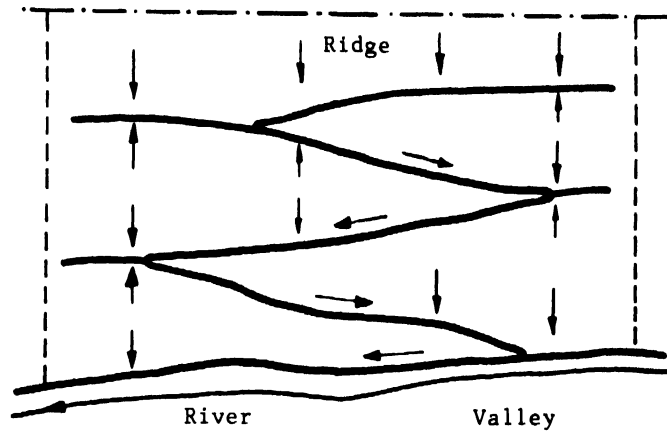


Fig. 7 SERPENTINE SYSTEM ON STEEP AND LONG SLOPES

When forest road systems are planned on slopes, special efforts should be made to keep the number of switchbacks to a minimum to avoid zig-zag patterns. The owners of small forests in mountainous areas should cooperate to construct a common advantageous road system as shown in Fig. 8.

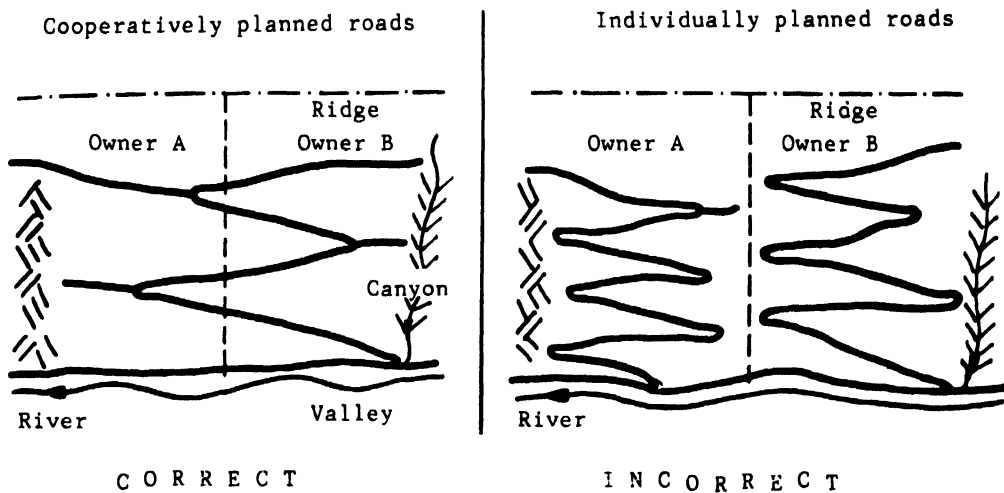


Fig. 8 CORRECT AND INCORRECT DEVELOPMENT OF A FOREST ROAD SYSTEM ON A SLOPE

(iii) Ridge roads

These roads are the cheapest in steep and irregular terrain. However, they open up the area to only a very limited extent and are used for yarding uphill in difficult terrain. They should be planned only if the valleys are actually inaccessible or the slopes are too steep or unstable. (See Fig. 9.)

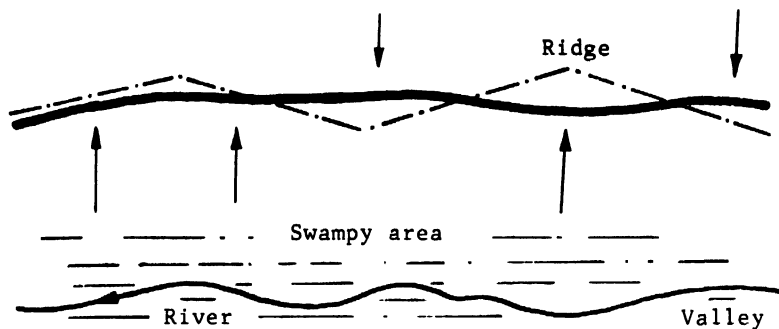


Fig. 9 FOREST ROAD ALONG A RIDGE

(iv) Mountain and hill tops

Circular roads can be located to open up the tops of mountains and hills. (See Fig. 10.)

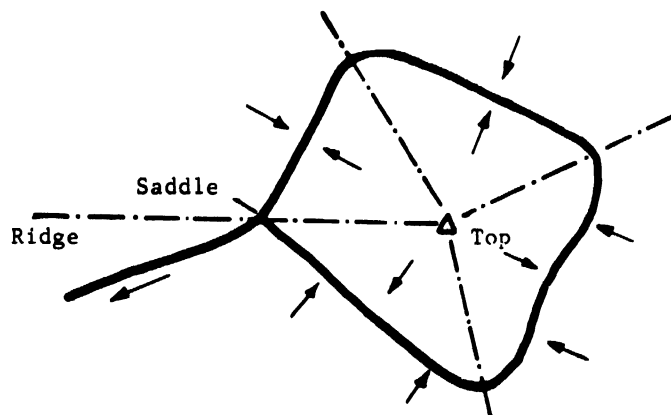


Fig. 10 CIRCULAR ROAD AROUND A HILLTOP

(v) Valley basins

Valley basins in hilly or mountainous terrain are developed by means of a main valley road and a circular road system on the slopes, provided that the terrain is not too difficult. (See Fig. 11)

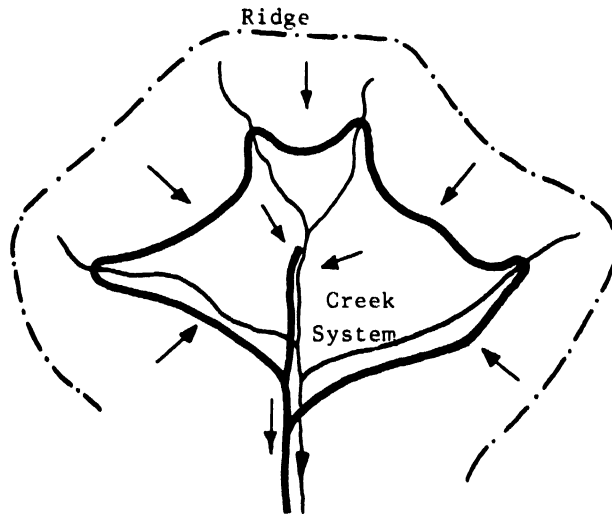


Fig. 11 FOREST ROAD SYSTEM IN A VALLEY BASIN

(vi) Logging areas beyond inaccessible terrain

Such areas can sometimes be opened up from the opposite side by crossing the ridge at a suitable saddle point and using adverse grades.

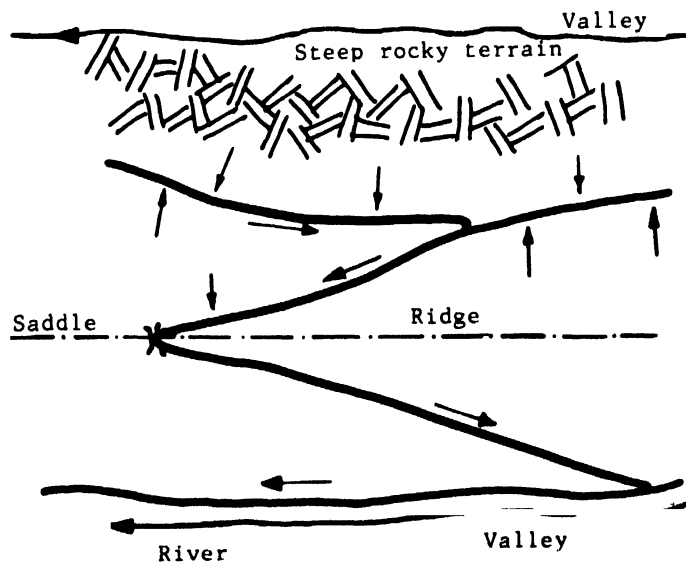


Fig. 12 ROAD DEVELOPMENT FROM THE OPPOSITE SIDE

### 3. PRACTICAL PLANNING PERFORMANCE

#### 3.1 Preparation

All available information about the area in question should be assembled as a prerequisite to the reconnaissance. This material should include, for example, topographic maps and aerial photographs, geological, hydrological and soil data, maps of ownership and plans of multiple land use, forest management and forest transportation.

##### 3.1.1 Topographic maps

Modern topographic maps are made from aerial photography and are indispensable for reconnaissance in large areas. In Europe, topographic maps of high standard and accuracy are normally provided by the national survey authorities. The usual scales are 1:50 000 or 1:25 000. The maps have contour lines with intervals of 10 to 20 m.

##### 3.1.2 Special maps for management and logging

Modern forest maps with scales of 1:10 000 or 1:5 000 show many important details of topography, streams, timber cover, age classes and existing transport systems.

Geological maps are very useful and provide a general survey of soil and subsoil conditions.

##### 3.1.3 Aerial photographs

Aerial photographs are often used in addition to topographic maps. They show much detail such as land use and forest cover.

Aerial photographs are still the sole source of reconnaissance information in many countries. In flat and slightly rolling terrain these photographs can be directly used as 'photomaps' since they reveal distances. For mountainous terrain aerial photographs should be transformed to orthophotomaps. An ideal type of material is the orthophotomap with contours, which combines photographic effect with map accuracy.

The normal scale of aerial photographs used during fieldwork is about 1:15 000. Photomaps are enlarged to scales of 1:10 000 or 1:5 000.

##### 3.1.4 Pre-reconnaissance data

Besides maps and photographs many other types of information are required. For overall knowledge of the area, data on its location, climate and size are collected. Geological and hydrographic data, details of forest management (timber resources, growing stock, increment, logging costs, analysis of the existing transportation system) are also required. Practical experience of previous forest road construction in the area is very useful (subsoil, gravel deposits, cost).

Special consideration should be given to problems of environmental protection and multiple-use coordination in cooperation with competent specialists.





## 3.2 Field reconnaissance

No fixed methods of field reconnaissance can be recommended since local conditions and objectives vary widely. But it is emphasized that a thorough personal reconnaissance conducted on the ground is indispensable to learn the peculiarities of the terrain and the feasible routes. Personal participation by the responsible engineer in field reconnaissance in close cooperation with the local staff must not be replaced by studies of maps, aerial photographs or even helicopter flights. The latter are useful but can only complement careful field work.

### 3.2.1 Work procedures

If modern maps with contours are available, general drafts of several variants of the forest road net can be plotted on paper quite easily. But a first overall reconnaissance is necessary beforehand in any event.

As has already been mentioned the main roads are normally located in the main valleys and the slopes should be subdivided by feeder roads. Account must be taken of the points of junction with the public road net; the terrain; the control points; and the recommended grades and road spacing.

Field reconnaissance to verify the preliminary drafts is most important. If modern maps are not available, the work begins immediately with this reconnaissance.

Activities should be carefully planned in advance for timing and organization. Large areas must be divided into several planning units. Problems of climate, travel, housing, supply of food and drinking water must be taken into consideration.

During this reconnaissance the engineering crew must walk along all main and side valleys and cross the slopes and ridges of the area. The topography is carefully checked against the maps and photographs or - if this material is not available - it is noted in drawings and sketches. All relevant control points and their elevations are checked:

Positive control points are important advantageous places for road construction or logging. These include bridging points, saddles on ridges, gentle slopes for better alignment, suitable places for switchbacks and landings. Gravel deposits which can be developed within the road system are very important especially for soils with low bearing capacity;

Negative control points such as steep slopes, rock, swamps, unstable slopes, deep canyons and very irregular parts of the terrain are disadvantageous and should be avoided if possible.

During the field reconnaissance the terrain is explored in detail. Preliminary paper locations are corrected or feasible routes are directly selected in the field. Final comparisons and rough cost estimates lead normally to only a few feasible variants of the general road system.

It is recommended, even for general plans, that the corridors of the selected main routes be checked by means of field controls. In mountainous terrain where the lines are "grade controlled", the engineer with his crew (two helpers and two brush-cutters) locates trial lines using a clinometer for grade and a drag rope for distance. These lines should be marked on trees with plastic flagging. During this phase unexpected obstacles may still be found, so corrections lead to feasible locations.

The final design of the general plan for the forest road net should be selected by the location engineer and the local staff in cooperation with specialists on forest resources, environment and multiple land use.

### 3.2.2 Instruments and equipment

Nowadays mainly modern hand-held instruments are used in forest road engineering. These instruments are small but accurate.

<u>Instruments and equipment required</u>	<u>Use</u>
Barometric altimeter	Elevations above sea level
Clinometer	Grades and side slopes
Compass	Bearings (azimuth)
Drag rope (nylon), 50 m	Distances
Pocket stereoscope	Stereoscopic view of aerial photographs

Additional equipment:

Engineer's case with pencils, rulers and scales, protractor, field notebook, maps and aerial photographs, plastic flagging.

#### Instruments recommended:

##### Barometric altimeters

THOMMEN pocket altimeter (made in Switzerland) is a small pocket instrument for general surveys, with an accuracy of  $\pm 20$  m. Price about US\$ 150.

PAULIN altimeter (made in Sweden) is a very accurate instrument with an accuracy of  $\pm 5$  to 10 m. Price about US\$ 900.

##### Clinometers

MERIDIAN clinometer (made in Switzerland) is a small pendulum device with a fixed optical system. The most suitable model, MC 1002, has two lenses for separating uphill and downhill readings to 100 percent both ways. Price about US\$ 100.

SUUNTO clinometer (made in Finland) is a small pocket instrument with a moving scale card. Normally the type PM-5/360 PC with scales of percent and 360 degrees is used. Price about US\$ 70.

### Compasses

During field reconnaissance, compasses with a protractor base can be advantageously used. There are many types. The following can be recommended:

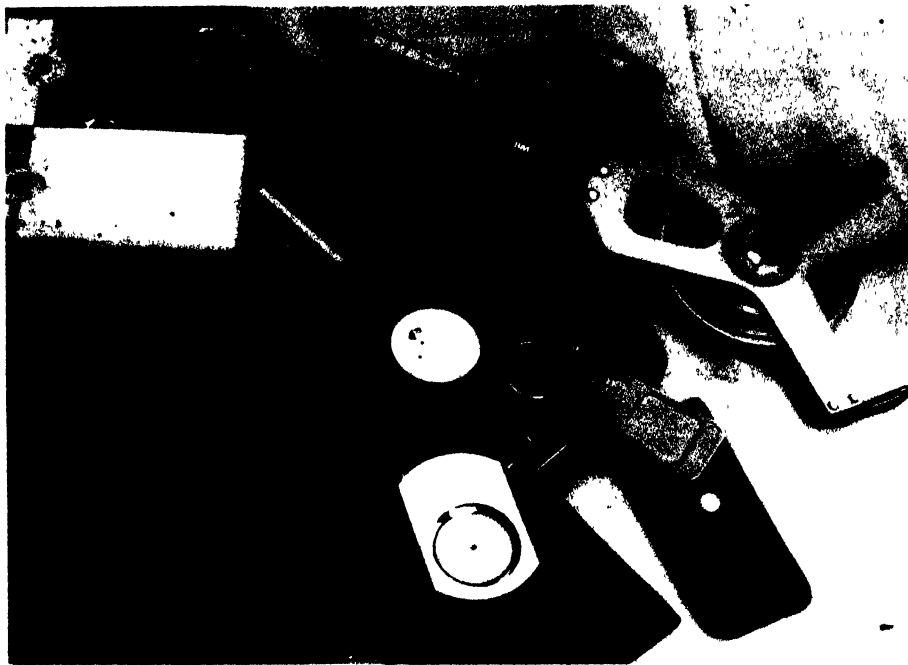
BEZARD (made in Germany). Price about US\$ 90.

SILVA (made in Sweden). Price about US\$ 30.

For more accurate surveying purposes compass instruments without a protractor base are recommended.

SUUNTO (made in Finland) is an excellent instrument with a reasonable price of about US\$ 60.

MERIDIAN (made in Switzerland). Price about US\$ 90.



Engineer's case of instruments  
(Photo: O. Sedlak)

### 3.3 Elaboration of the general project

The general project represents the results of the field reconnaissance and route selection. The paperwork consists of a written report and survey maps and plans.

#### Paperwork

The technical report consists of the following:

- a) Summary - mainly in the form of tables (routes, length, cost);
- b) Description of the area and of the previous existing management and logging systems;

- c) Reasons for developing a new road system and improvements expected. Description of the new logging system;
- d) Description of the planned forest road system (principles of layout and design/ considerations of road spacing), details of the new individual routes;
- e) Recommended methods of construction and organization. Time table;
- f) General cost estimate. If no local data are available, approximate cost may be determined by using Sundberg's formula:

$$C_1 = 230 + (17 \times SL) + (660 \times ST_i) + (30 \times SL \times ST_i)$$

Where:

$C_1$  = direct cost in US\$ per km for road standard  
(supervision and overheads excluded)

SL = mean side slope in percent of the terrain

$ST_i$  = road standard, 0 for skidding trails, 1-2 for secondary roads, 3 for main and access roads.

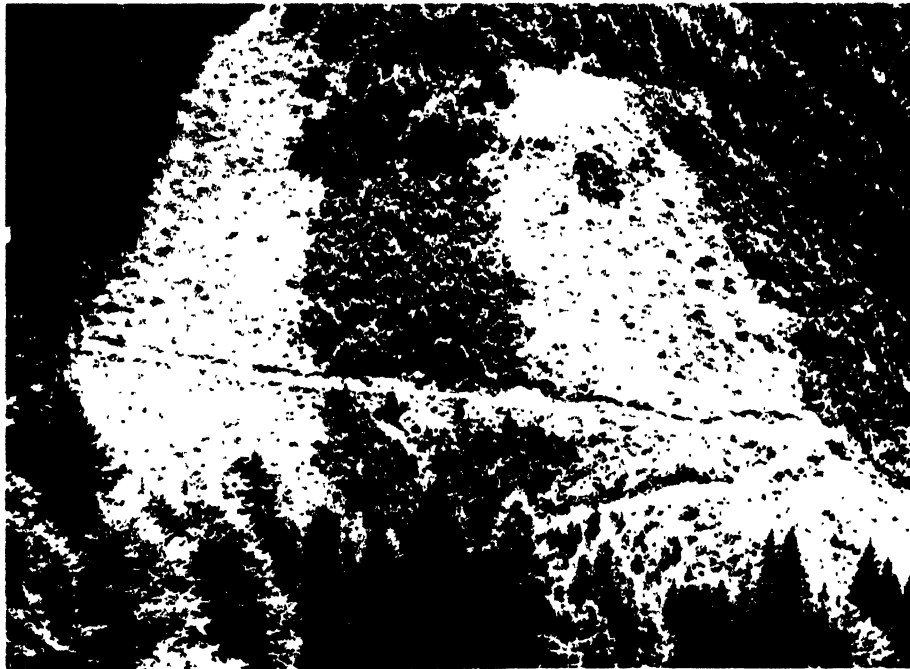
#### Drawings and plans

Section of the topographic map (scale 1:50 000) with the draft of the planned road net.

Survey map (scale 1:10 000) with the detailed draft of the planned road system.

General cross-sections (scale 1:50)

General drafts of structures (culverts, bridges, retaining walls, scale 1:50 ).



Well-planned forest road networks allow intensive forestry operations. Above: small clearcut areas next to regenerated and mature stands. (Photo: R. Heinrich)

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Leykam Log-Line plastic chutes of 5 m-long U-shaped sections,  
coupled together and used for gravity transport of timber.  
(Photo: R. Heinrich)

## FOREST ROAD PLANNING, LOCATION AND CONSTRUCTION TECHNIQUES ON STEEP TERRAIN

by

Otto Sedlak  
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### 1. INTRODUCTION

The more complicated and expensive a road construction, the more intense and precise the planning methods which should be applied. Precise planning methods are required where roads are to be manually constructed, as still occurs in countries with underemployment and low wage costs; a precise location and design according to classical engineering methods should be established. This procedure includes a preliminary survey of the route; mapping of strip contour; levelling; the survey and plotting of cross-sections; mapping and design; final location; and mass balance.

Simpler methods of location have been developed for the mechanized construction of forest roads in the mountains of Austria. Normally the location of the gradeline (in Austria called the zero line) is sufficient where the gradient is the controlling factor. Since forest roads are constructed by machines with high performance, an exact costing of the earthwork is not required.

To find the most feasible route, however, it is necessary to run several trial gradelines. Such simple but expedient methods must not be confounded with careless planning, and they require skill and experience.

Since mechanized road construction is most frequently used, this simple gradeline method will be discussed during the course.

### 2. LOCATION AND DESIGN

The location and design of a forest road may be divided into two phases:

#### Direct location in the field

In hilly or mountainous country the gradeline of a forest road is located directly on the ground. In flat country it is mainly the horizontal alignment which is the controlling factor and the tangents are located depending on the general layout.

#### Textual elaboration: technical report, drawings and cost estimates

This textual part of the project contains the information necessary for construction and supervision as well as for review and approval.

#### 2.1 Location

##### 2.1.1 Location in flat or rolling country

As in mountainous country several variants of alignment within the generally selected corridor of the road have to be studied to find the best route. The final tangent-alignment of the centreline is staked with preference given to a curvilinear alignment rather than to

very long tangents (see Fig. 1). The points on the curves are determined by means of deflection angles, the radius and curve tables. Care should be taken with minimum radius, smooth transitions and minimum gradient.

Instruments used: ranging poles (rods), steel or fibreglass tapes, drag rope, pocket compass, altimeter, theodolite or clinometer or surveyor's level.

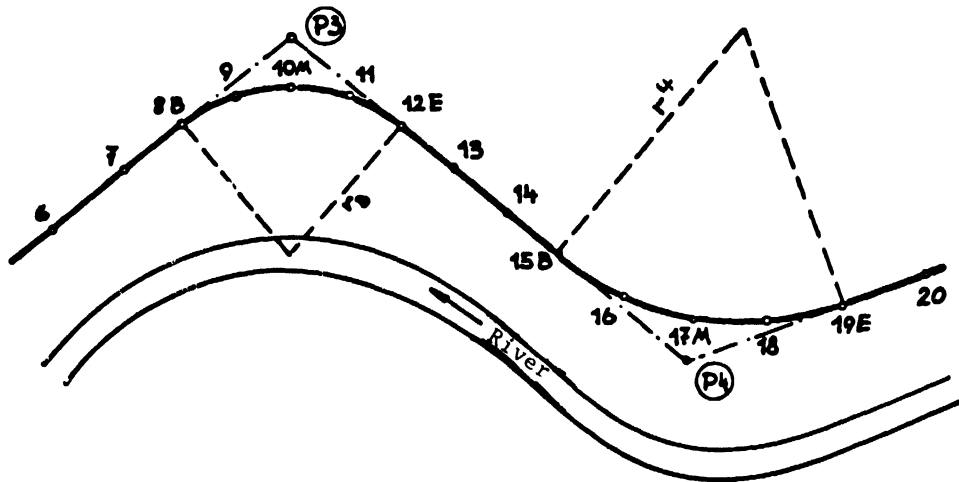


Fig. 1 ALIGNMENT IN FLAT COUNTRY

B and E = beginning and end points of curve  
M = middle point of curve  
P = polygon point

Parabolic curves can be simply staked by means of a measuring tape and ranging poles.

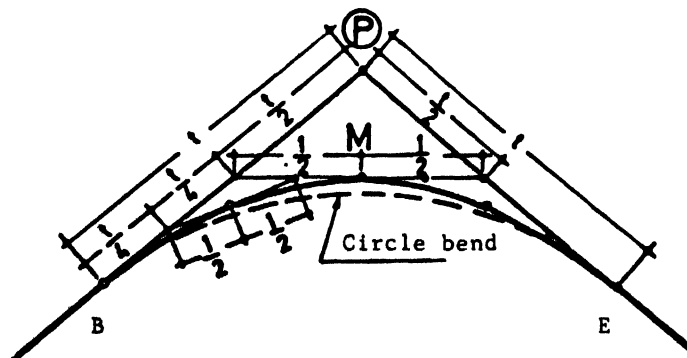


Fig. 2 PARABOLIC CURVE



### 2.1.2 Location in hilly and mountainous country

Forest roads in hilly and mountainous terrain are mainly grade-controlled and situated on slopes. The gradeline which is the guideline for mechanized road construction is located directly in the field and is a staked line with the required gradient adjusted to the ground. It represents the intersection between the subgrade of the road and the slope.

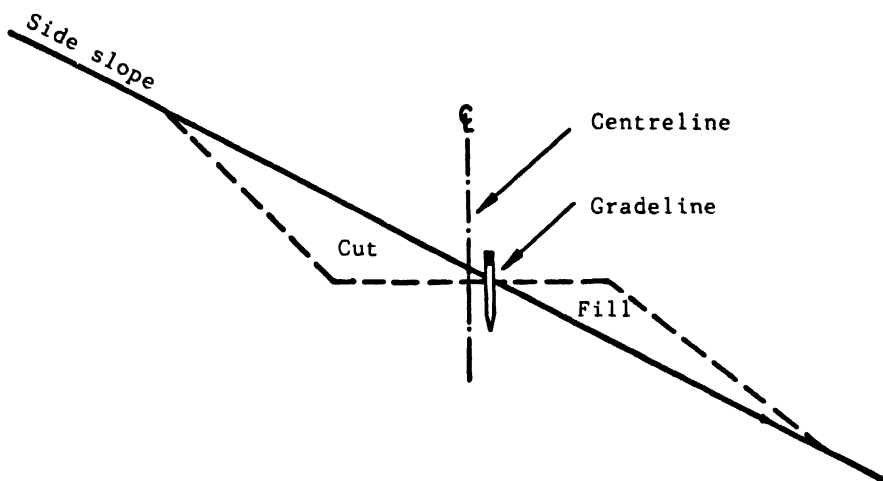


Fig. 3 POSITION OF THE GRADELINE

The gradeline can be quickly and accurately staked by means of a hand-held clinometer. To determine the best route it is recommended that one or more trial lines be run. These are only flag lines marked by tying coloured plastic flagging to trees or branches.

The centreline is additionally staked only along difficult sections of the route where alignment and horizontal control are important factors (e.g. in bridge locations, embankments, long cuts in spurs).

#### 2.1.2.1 Gradeline surveying techniques

For staking the gradeline the clinometer and a suitable target (painted plywood or aluminium sheet, size about 30 by 20 cm) are adjusted to the same height on two poles.

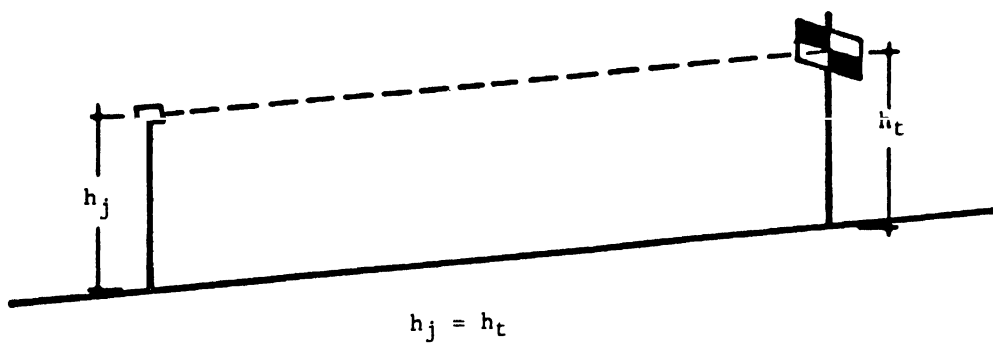


Fig. 4 CLINOMETER AND TARGET

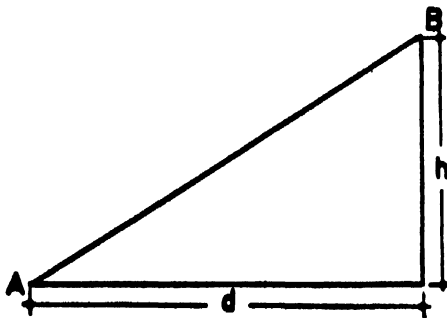
This simple equipment has to be checked before use. Two points are fixed on the ground at a distance of about 20 to 30 m and the gradient is measured both uphill and downhill. If the readings are equal then the adjustment is correct.

The surveyor needs a crew of one target man and about three helpers for cutting underbrush and staking. He always walks ahead of the crew and aims his clinometer back to the sighting mark. The distances between the points of the gradeline should be fairly equal ( 30 to 50 m for flagging, 20 to 30 m for staking).

The maximum gradient for downhill transport should not exceed 9 to 10 percent for main roads or 12 percent for secondary roads. Where uphill transport is required the maximum grade should be 6 to 8 percent. A minimum grade of 2 to 3 percent is necessary for good drainage. A level grade should never be used over a long distance because precipitation water will remain on the road.

During the first trials in the selected corridor the surveyor determines the intermediate control points and the grades required. A pocket altimeter and a 50-m drag rope are useful aids for longer routes.

The individual gradients between control points are computed by means of the difference of altitudes over the distance.



$$g(\%) = \frac{h}{d} \times 100$$

$h$  ... difference of altitudes B - A

$d$  ... horizontal distance

Fig. 5 GRADIENT BETWEEN CONTROL POINTS

In case it is necessary to reduce or to increase the gradient of the gradeline, the maximum difference between two of its grades should not exceed 3 percent provided the average distance between the stakes is about 20 to 30 m. Smooth transitions in the road profile will be obtained in this way. This rule must be observed especially in laying out switchbacks and in the transition from crest to valleys or vice versa.

The gradeline has to be staked as closely as possible to the future centreline to avoid major differences of grade between the gradeline and the final road. In irregular country with ridges and valleys the gradeline reflects the breaks in topography and is longer than the final centreline. Allow for it and reduce the gradient (see Fig. 6). A common mistake made by inexperienced personnel is to set stakes too far up depressions or on the outside of ridges, keeping a constant grade. The grade of the centreline in these curves will be too steep.



### 2.1.2.2 Method of locating the gradeline

A feasible corridor for the road is determined by reconnaissance, so the locating engineer has some idea of the general conditions, the control points, and the ruling grades of individual sections. Nevertheless, time would be wasted by driving in stakes during the first trials since corrections are usually necessary. Therefore it is recommended that the location and the survey be divided into four stages:

1. A trial line with the estimated grade is flagged, without using a target and poles. The engineer sights back on the helper who should carry a sighting mark at the eye height of the surveyor. A drag rope is used to determine roughly the distances between control points. The line is marked by flags. This first trial line will not reach the desired control point and the grade will have to be corrected by calculating the height difference over the distance:

$$\text{Correction of grade} \dots + g (\%) = \frac{\Delta h}{d} \times 100$$

It should be mentioned that the difference between slope and horizontal distance of the gradeline is so small that it can be ignored.

2. In the case of a major difference a second gradeline is run, using the improved gradient on the way back. A different colour flagging should be used to avoid confusion.

3. The two preceding trials can be regarded as a detailed reconnaissance. The final location can now commence using the clinometer and target adjusted with poles.

The surveyor notes the following data in his field book during location of the road: number of the stake, the gradient, representative side slope, estimated rock component, additional mass of earth and rock which exceeds the normal profiles, description of terrain, culverts and structures (see Fig. 8).

Stake		14 cm					14 cm	
		from	to	Gradient g (%)	Distance d (m)	Bearing b (°)	Side slope s (%)	Rock Excavation r (%)

Fig. 8 FORM FOR THE FIELD BOOK

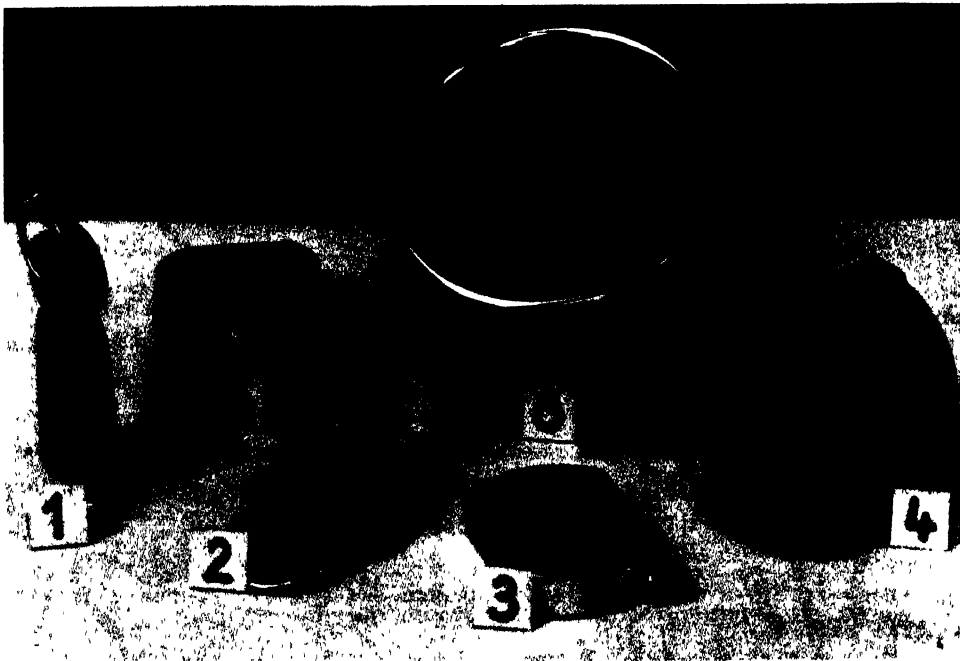
4. The staked gradeline is surveyed using a compass and tape, with the surveyor walking back over the route. Again he goes ahead of the crew and sights back at the target. By using a second signal ahead, he can check his bearings with the reverse scale of the compass. Both bearings are noted and differences should not exceed one degree.

A tape crew of three men measures the distances between the stakes. The readings are rounded down to full decimetres.

During this fourth stage the surveyor has only to note the bearings and distances.

#### 2.1.2.3 Instruments

The instruments described for general development of forest roads are also used for location and survey. Instead of a drag rope, a tape (30 to 50 m, steel or fibreglass) is used to measure distances accurately.



Survey instruments (Photo: O. Sedlak)

- |                        |                               |
|------------------------|-------------------------------|
| 1. MERIDIAN clinometer | 4. BEZARD compass             |
| 2. MERIDIAN compass    | 5. THOMMEN pocket altimeter   |
| 3. SUUNTO compass      | 6. PAULIN precision altimeter |

#### 2.1.2.4 Performance

The level of performance in detailed field reconnaissance, location of the road and survey of gradelines depends on the accessibility of the terrain, on the topography, on the forest cover and last but not least on the experience of the road engineer and his crew. The following data can be used for estimates:

<u>Conditions</u>	<u>Personnel required</u>	<u>Time required</u> (hrs/km)
Normal (forests in moderate climate, easy terrain)	1 engineer 3 workers	5 - 7 15 - 20
Difficult (forests in tropical areas, difficult terrain)	1 engineer 5-6 workers	8 - 12 40 - 60

## 2.2 Textual elaboration of the project

The field data on the direct gradeline location are evaluated for plans (paper location). A technical report with estimates of earthwork quantities and costs is also prepared.

### 2.2.1 Maps and plans

A section of the topographical survey map (scale 1:50 000 or 1:25 000) shows the general location of the planned road within the existing transport system.

The gradeline projection is shown in a detailed map section (scale 1:10 000 or 1:5 000). The gradeline is plotted on transparent paper together with checking points on the map and the centreline is drawn as a freehand line close to the gradeline. This line has to be critically examined as regards horizontal controls (alignment, minimum radius) and feasibility. Several cross-sections at critical points will improve this paper location.

The final design is made in sections of 100 m each, using a divider, and is transferred to the master sheet of the map. Culverts and structures as well as landings and peculiarities of the terrain are drawn on the map using simple symbols.

In copies of the design plan the roadline is traced out in red ink. Rivers and small creeks are traced in soft blue pencil and ridges in brown. Forest boundaries are drawn in green. The skidding directions can be shown with arrows.

Typical cross-sections for earth and rock are designed as standard drawings for the construction. (See Fig. 9).

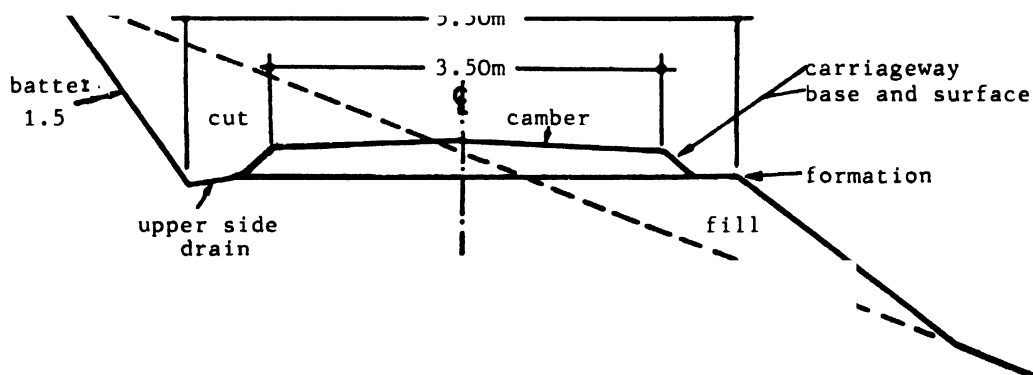


Fig. 9 CROSS SECTION



A profile of the gradeline is not usually plotted provided the direct field design of all vertical checkpoints is correct. Only a table in the form of a written grade profile is prepared, as illustrated below:

Stake	Station (hm)	Distance d (m)	Gradient g (%)	Remarks

### 2.2.2 Technical report

This report contains:

- description of the forest area (situation, geological conditions, topography, size, forestry data)
- existing transport system (logging methods, long-distance transport, costs)
- transport system to be developed
- description of the project
- construction (machinery, equipment, methods, organization)
- written grade profile

### 2.2.3 Estimating the costs of construction

Costs for mechanized forest road construction are as similar as costs for machines, despite wide differences in local conditions. Within certain limits, the costs for mechanized earthwork and transport are comparable.

However, local conditions do affect economic construction. In countries with low wage costs and underemployment, modern machines are relatively expensive, especially with regard to rising prices for fuel. Here manual or only partially mechanized construction may still be the best solution. In a combined construction method the major earthwork is done by machines, and only the minor earthwork (e.g. shaping cut slopes, drains, culverts) is done by hand.

#### 2.2.3.1 Costs of preliminary work

##### Clearing the way

The costs of clearcutting the road corridor are not normally allocated to the construction cost if the timber can be used. The corridor has to be cleared of branches and underbrush and the material deposited at the downhill edge of the roadway in order to protect the standing timber.



### Preblasting of stumps

If explosives are available, it is recommended that all stumps with diameters of more than 40 to 50 cm be preblasted, especially in flat country. On slopes only the stumps close to the gradeline are blasted. Average cost per stump is about US\$4-6. Blasting stumps is not necessary if a heavy bulldozer (for instance the Caterpillar D-8) is employed.

### Drains

Wet areas should be drained by a fishbone system of drains some weeks before the earthwork is started. The current average cost per metre is about US\$0.8-2.0.

#### 2.2.3.2 Costs of earthwork

Bulldozers with A- or S-blades are still the most important machines in forest road construction. These machines combine high performance with low cost of production. However, in steep terrain bulldozers cause considerable damage by sidecasting material. To meet the demands of environmental protection, therefore, hydraulic excavators are being increasingly employed in mountainous terrain.

Several methods of calculating the costs of earthwork can be applied:

- (a) Calculating the quantity by means of side slopes and standard cross-sections (for example, refer to Hafner, see Figs. 11 A to D). The costs are calculated on the basis of the total volume and the cost per  $m^3$ ;

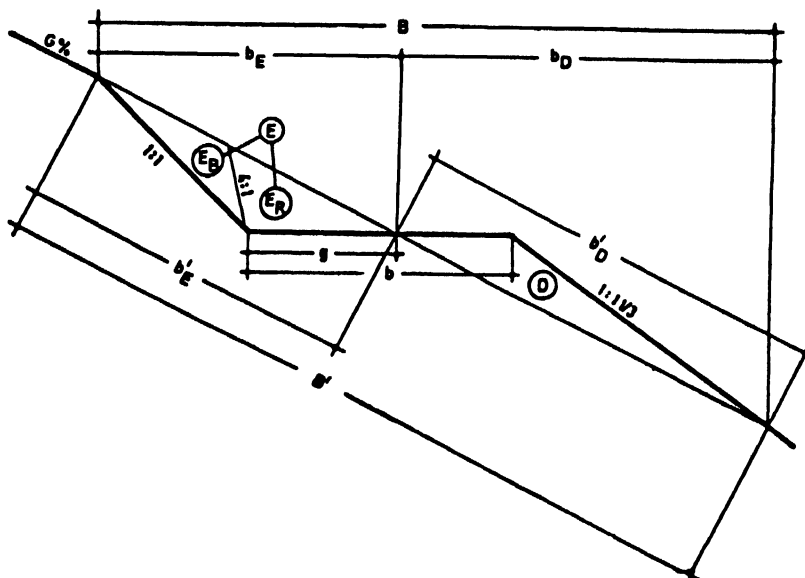


Fig. 11 A CROSS-SECTION (SLOPE PROFILE) OF EARTH - EXAMPLE FOR  $b = 4$  m  
(refer to Hafner)



ROCK

G %	$\epsilon_m$	$b_m$	$m^3/m$	$\frac{b_E}{b'_E}$	$\frac{b_D}{b'_D}$	$\frac{B}{B'}$
40	2.50	4.50	1.36	2.70 2.95	4.00 4.35	6.75 7.30
50	2.50	4.20	1.74	2.80 3.10	4.75 5.30	7.55 8.40
60	2.60	4.00	2.30	2.95 3.45	6.20 7.25	9.20 10.70
70	3.00	4.10	3.66	3.50 4.25	10.90 13.30	14.40 17.60
80	4.00	4.00	7.62	4.80 6.10	00	5 + 6.5 +
90	4.00	4.00	8.78	4.90 6.60	00	5 + 7 +
100	4.00	4.00	10.00	5.00 7.10	00	5 + 7.5 +

Fig. 11 D CALCULATION OF EARTHWORK COSTS: ROCK

- (b) Estimating the average volume per metre depending on the mean side slope. Costs are calculated as in (a);
- (c) Estimating the average machine cost per metre on the basis of local empirical data.

Table 1

AVERAGE PRODUCTION AND COST OF A MEDIUM BULLDOZER (WEIGHT 12-16 t)  
CONSTRUCTING A SECONDARY FOREST ROAD IN THE MOUNTAINS OF AUSTRIA

	Terrain conditions		
	Simple	Medium	Difficult
Average side slope in %	30	50	70
Production in metres/hour	12 - 15	9 - 12	6 - 9
Cost per metre in US\$	2.5 - 3	3 - 4	4 - 6

Machine cost per productive hour: US\$ 35-40

Motorgraders (medium weight, 10-14 t) are employed in forest road construction mainly for battering, shaping and draining. Production is greatly influenced by the skill and experience of the operator.

In shaping the final profile and the cut slope the average production is between 50 and 100 metres per hour. The costs are about US\$0.3 - 0.7 per metre.

#### 2.2.3.3 Rockdrilling and blasting

Rockdrilling in difficult terrain in Austria is performed with high-powered pneumatic machines. Smaller compressor units with hand-held hammers are employed for minor roadwork only.

The costs for blasting depend on the type of rock and the percentage of rock in the cross-section (rock volume per m), as well as the equipment.

Average costs for drilling and blasting are now about US\$5 per m<sup>3</sup>.

#### 2.2.3.4 Drainage

Forest roads with a maximum grade of 10 percent are drained by means of mountainside road drains and concrete culverts. In Austria prefabricated concrete pipes are available at relatively low prices and are transported to the construction site by truck.

If such pipes are not available or too costly, culverts made from timber or concrete slabs can be constructed directly at the site. Even old barrels welded together can be used. If no suitable material for culverts is available, the mountainside road drain has to be drained by simple surface waterbars made from timber.

In areas with high annual rainfall and thunderstorms the drainage system has to be carefully planned and constructed to protect the road against erosion and destruction.

Prefabricated concrete pipes for culverts are 1 m long and have the following weights and prices in Austria:

Diameter in cm (length 1 m)	Weight in kg per m	Price on the construction site in US\$ per m
30	100	6
50	270	13
60 heavy duty	610	35
80 ditto	1 000	53
100 ditto	1 700	80

In Austria concrete pipes for culverts are usually laid by hydraulic excavators. The cost depends on their diameter and the type of subsoil and can be estimated on average at about US\$10-15 per metre. The well and apron for one culvert may be calculated at about US\$25-40.

These pipes used in forest road construction have a diameter of up to only 1 m. Specially reinforced pipes have diameters of up to 1.5 m, but these are very heavy.

A compromise between a culvert and a small bridge is a culvert of corrugated steel sheets. This material is produced in various sizes for different systems and diameters and is fitted together at the site.

Such culverts are costly, but advantageous at difficult and inaccessible construction sites. The price for culverts with diameters of 1.5-3 m is about US\$250-600 per metre.

#### 2.2.3.5 Base

The amount of base material depends on the bearing capacity of the subsoil, the width of the carriageway and the quality of the base material itself. On loamy and silty soils with low bearing capacity, expenses for the base material may be up to 60 percent of the total cost.

BASE MATERIAL REQUIRED FOR A CARRIAGEWAY 3.50 m WIDE  
(EMPIRICAL DATA FOR AUSTRIAN CONDITIONS)

Subsoil	Clay/loam	Loam/sand	Sand/stone
Bearing capacity	low	medium	high
Base material (m <sup>3</sup> )	2.5 - 3	1.5 - 2	0.5 - 1

It is most important for economic construction to find gravel deposits as close as possible to the road site, since transport costs are high. If a gravel pit or a quarry can be developed along the road to be constructed, the cost can be considerably reduced.

The base material is loaded from the deposit on to heavy dump trucks by tracked or wheeled loader or by a hydraulic excavator. The loading production is about 40-50 m<sup>3</sup> per hour under average conditions. The cost is about US\$0.6-0.8 per m<sup>3</sup>.

The normal carrying capacity of two- or three-axle dump trucks is 6-10 m<sup>3</sup> per truck. The average transport cost amounts to about US\$0.5 per m<sup>3</sup> per km for distances of between 10 and 20 km.

The base material is dumped on the road-bed and spread and shaped with small bulldozers or motorgraders. The costs are about US\$0.4 - 0.5 per m<sup>3</sup>.

Final grading and compacting of the base and surface is done with motorgrader and vibro-drum roller.

Machine	Production (m per hour)	Cost in US\$ per m
Grader	150 - 250	0.3 - 0.4
Vibro-drum	80 - 100	0.4 - 0.5
Total cost		0.7 - 0.9

### 2.2.3.6 Structures and other items

Bridges, big culverts and special structures (retaining walls, timber crib abutments) are calculated individually. Planning and supervision account for 5 percent of the total cost. Unforeseen expenses should be allocated 10 percent of the total cost.

Items	Units	Price per unit	Costs
1. Preparation (felling and clearing, preblasting of stumps)			
2. Earthwork			
3. Rock blasting			
4. Drainage (culverts, waterbars, drains)			
5. Construction of the base (gravelling, grading, compacting)			
6. Structures			
7. Planning and supervision	5%		
8. Unforeseen expenses	10%		

Fig. 12 FORM FOR ENGINEER'S ESTIMATE

Table 2

### SUMMARY OF FOREST ROAD COST IN AUSTRIA

Average empirical data for easy and medium terrain in US\$ per metre

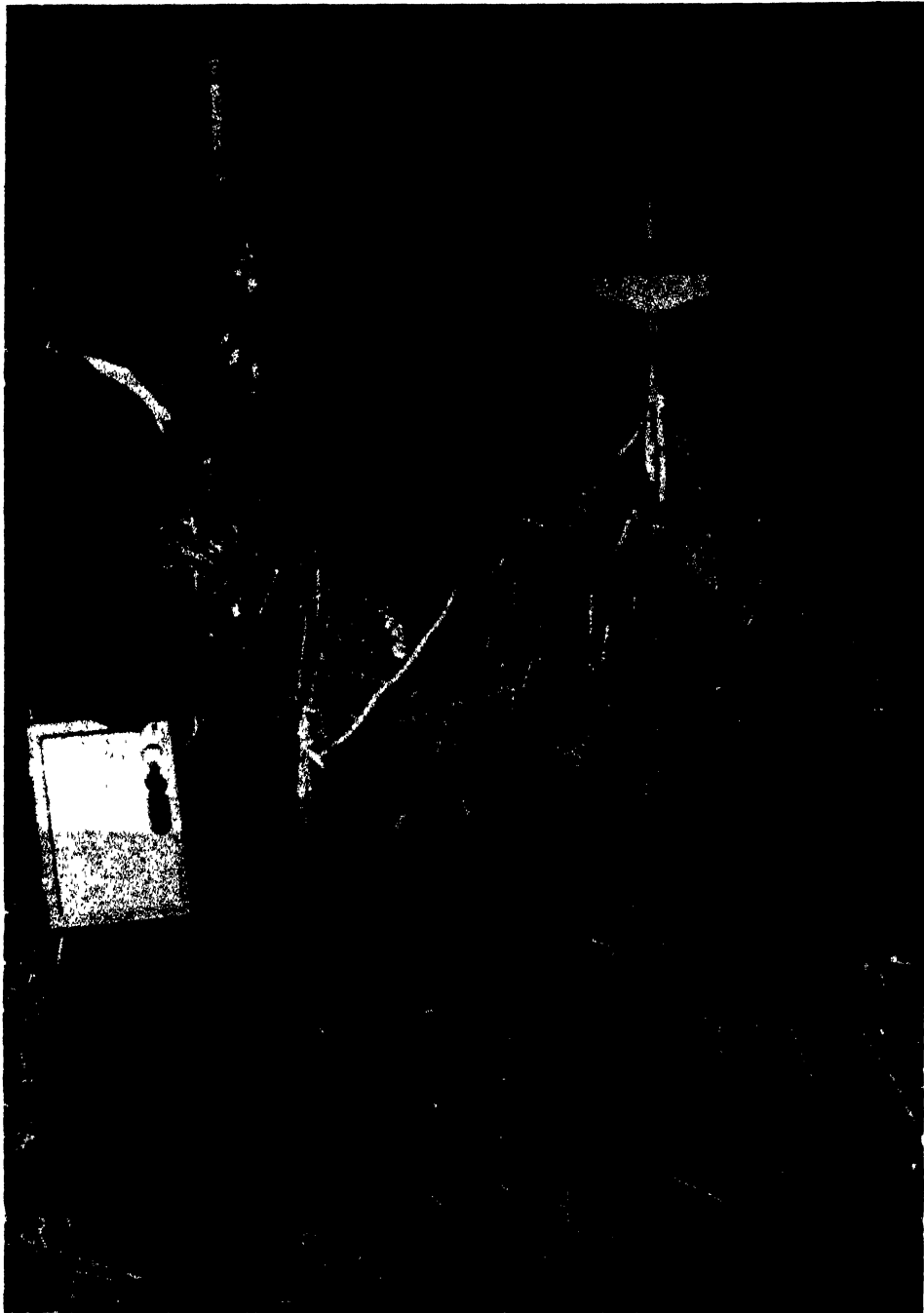
Road standard	Bearing capacity of subsoil		
	low	medium	high
Main road	26 - 30	17 - 19	11 - 13
Subsidiary road	23 - 26	13 - 15	8 - 10
Skidding road		1.5 - 4	

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Heavy-duty tractor engaged in road formation work  
(Photo: O. Sedlak)



Surveying a forest road with a clinometer  
(Photo: E. Pestal)



## FOREST ROAD-NET PLANNING AND WOOD HARVESTING

by

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FAO Forestry Department

### 1. INTRODUCTION

Integrated planning of the opening up of mountain forest resources is essential to ensure a steady supply of industrial roundwood on the one hand and to pursue forestry work so as to ensure preservation of the forests and the environment on the other. Integrated planning is especially important in view of the use of modern machinery for both road construction and forest harvesting, and the ever-increasing demand for wood.

Very often, in addition to the basic objectives, other matters must be taken into consideration - land tenure and local people's rights to and requirements of fuelwood and fodder and the interests of a village, district, county or country in water supply, scenery, wildlife, etc. For all purposes, whether of a productive or protective nature, a well-planned forest road-net is the basic element necessary to carry out the required work and to maintain the forests as a renewable resource.

#### 1.1 Road-net planning

Generally, the layout of a road-net depends on the timber resources, terrain conditions, type of forest operations (afforestation, silvicultural treatment, fire protection, cutting system, logging and transport methods), technical equipment and machinery, labour techniques and costs, as well as on the other resource factors to be considered. Careful attention has to be paid, when roads are planned and located in steep terrain, to avoiding and minimizing the erosional impact of roads on the environment.

Forest roads should, as far as possible, be planned with a view to conducting both present and future wood harvesting operations. Where extraction will be manual, a road-net must be laid out differently from one where cable cranes and/or tractors are to be operated. Figures to determine the efficiency of a road-net for a certain area are derived by relating the road length to total roundwood removals per year ( $m^3$ /year) or from the length of the road-net per hectare of forest area (m/ha).

#### 1.2 Aerial photographs and maps

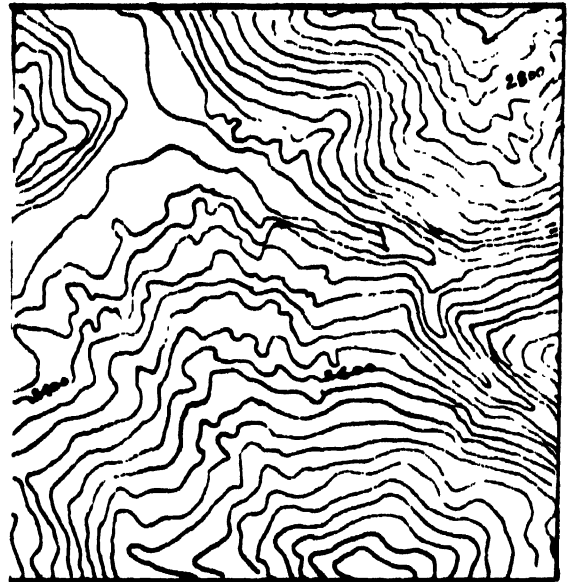
Aerial photographs facilitate planning forest roads as the planner may determine possible routings in the office by viewing the photographs through a stereoscope and eliminating unacceptable variants. In this way, labour and time-consuming road survey work on the ground can be reduced considerably. However, field reconnaissance and field checks are required to ensure that something has not been missed, and to arrive at an optimum road location.

Good topographical maps are essential, preferably with a scale not larger than 1:10 000. If good contour maps are not available, extensive field work is required to measure all main control points barometrically and to record detailed terrain features.

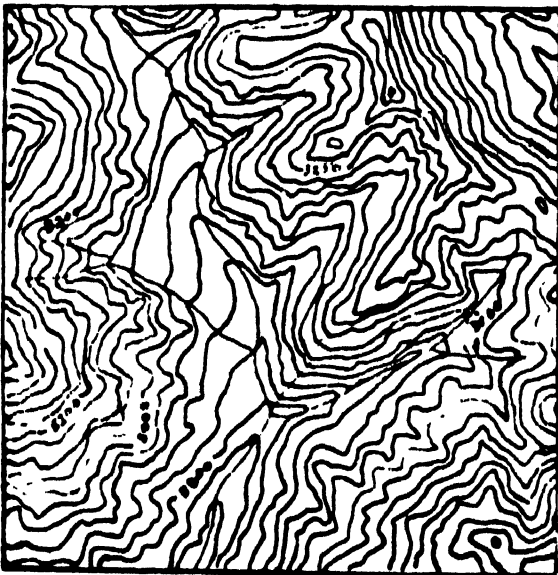
Figure 1 shows four different types of terrain, from easy to difficult, which can be recognized from the spacing and curvature of contour lines. (These examples are typical for Bhutan.)



Easy to medium terrain



Medium terrain



Difficult terrain



Very difficult terrain

Fig. 1 EXAMPLES OF DIFFERENT TYPES OF TOPOGRAPHY IN BHUTAN (SOUTHERN AND WESTERN, CENTRAL REGION)

Scale 1 : 50 000

Contour interval = 40 m

### 1.3 Road types

Roads in a forest road-net can be classified as follows:

(a) According to their position:

- main valley roads
- secondary valley roads
- slope roads
- feeder roads
- mountain ridge roads

(b) According to the construction:

- earth roads
- gravelled roads (mechanically stabilized)
- chemically stabilized roads
- roads with bituminous or oiled surface

(c) According to the intended use:

- truck roads
- tractor roads
- purely opening-up forest roads
- access roads
- multiple-use forest roads

(d) According to the importance:

- main roads (permanent and all-weather roads)
- secondary roads, feeder roads (seasonal roads)

### 1.4 Road standards

The standard of a road depends largely on its proposed end use, on the amount of harvestable and marketable wood per unit area, and on terrain conditions. The following road classification is suggested for steep terrain:

- Access roads
- Main forest roads
- Secondary forest roads, feeder roads
- Skid roads
- Skid trails

#### 1.4.1 Access roads

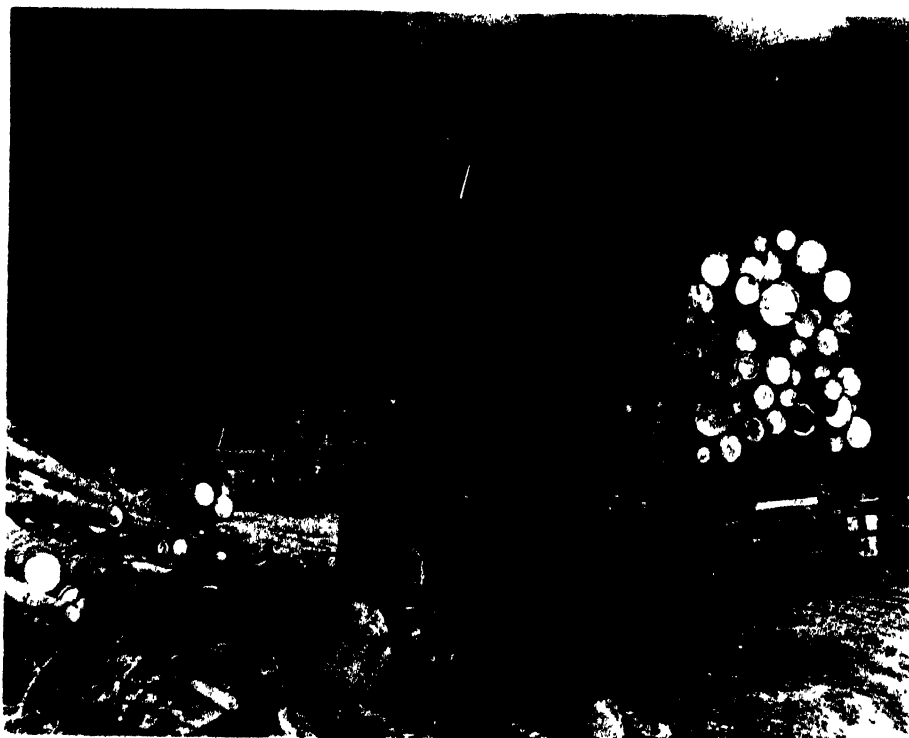
The main purpose of access roads, as their name suggests, is to provide access to the forests for the transport of people from villages to the forests and for the transport of roundwood from the forests to the wood-processing sites or terminals. Very often these roads are the links between the public roads and the main forest roads.

#### 1.4.2 Main forest roads

The basic road-net consists of main forest roads, usually where wood transport is possible throughout the year. The location of such roads must be decided from the point of view of their use. Very often they are needed for many years in forests with intensive management, where they are the key to all forestry operations. Engineering structures and drainage facilities appropriate to this long-term use are required. If the in situ road-base material does not have the bearing capacity to support heavy traffic throughout the year, it should be reinforced or entirely gravelled with adequately graded material. Generally, a gravel layer of 25 cm is sufficient.

#### 1.4.3 Secondary forest roads (feeder roads)

Secondary forest roads connect the landings to the main roads. They are normally used only temporarily and therefore are not gravelled. During the rainy period in Bhutan most transport operations are closed down. In fact, if the soil is soft, a single truck can completely destroy the surface by making ruts. Ruts can become a source of heavy erosion, often leading to the total destruction of a road. Therefore, it is better to close down vulnerable parts of the road-net during the rainy season. By careful planning, logging in the rainy season can be scheduled for those roads which are surfaced and will not be damaged.



Secondary forest road - truck loaded at log landing  
(Photo: E. Pestal)

#### 1.4.4 Skidding roads (trails)

These are used entirely by wheeled skidders and/or crawler tractors for wood extraction only. The width of the road generally does not exceed 3.5 m. To prevent gully erosion caused by concentrated surface water flow on steep skidding roads, water bars <sup>1/</sup> should be built into the road before the rainy season or at least after logging operations have ceased.

Table 1 gives suggestions for possible road classification in mountainous terrain in Bhutan.

Table 1

#### ROAD CLASSIFICATION

Road type	Road use	Road formation width (m)	Carriage-way width (m)	Maximum gradient in		Cost range estimate in US\$ <sup>2/</sup> per m road
				transport direction %	adverse direction %	
Main forest road	Truck, pickup, permanent	5.0	4.5	9	6	15-25
Secondary forest road	Truck, pickup, temporary	4.5	3.5	10(12)*	8	7-15
Skidding road	Wheeled skidder, wheeled tractor, crawler tractor	3.5	-	12(20)*	10	3-7

( )\* maximum gradient for short distances only

#### 1.5 Road-net density and spacing

In hilly and steep areas the road spacing and location are determined predominantly by the terrain and the wood harvesting system feasible under the prevailing conditions. As road construction and maintenance costs are generally higher in difficult and steep terrain than in flat and hilly areas, determination of the road-net density is of the utmost importance. It depends largely on the average extraction distance and the terrain conditions. Average extraction distance, in turn, depends on the extraction system to be used: cable logging, ground skidding with crawler tractor or wheeled skidder, or combinations of these.

<sup>1/</sup> Ridges of packed earth across the surface of the road

<sup>2/</sup> In 1979

Formulae are often used to estimate optimal road spacing.

The basic formula visualizes a road-net with parallel, equally spaced and endless roads. This, of course, deviates considerably from actual road patterns, especially in the mountains. Various authors have introduced modifications of the basic model in order to adapt it to reality. Von Segebaden used correction factors to modify the geometry. The correlation between the road spacing and average skidding distance can be expressed by the formula given below:

$$\bar{S} = \frac{a}{D} \quad \text{or} \quad D = \frac{a}{\bar{S}}$$

where:

$\bar{S}$  = average skid distance in kilometres

a = road efficiency factor 1/

D = road density in metres per hectare

An example is given below of the use of the above-mentioned formula to calculate the best road-net density, using the following assumptions:

Average extraction distance = 250 m = 0.25 km

Steep terrain, road efficiency factor = 8

The equation is as follows:

$$\frac{8}{0.25} = 32 \text{ m/ha}$$

Therefore, where conditions are as assumed in the above example, a road-net density of 32 m/ha would be required.

From experience gained in mountain logging operations some guideline figures for road-net densities (truck roads) have been developed which may serve for planning purposes. However, these would have to be checked and modified according to local conditions before being used for other purposes.

1/ The value of the factor "a" varies from between 4 to 5 in flat or hilly terrain and up to 8 in steep terrain.

Table 2

EXAMPLES OF ROAD-NET DENSITIES VERSUS TERRAIN FEATURES

Description of terrain, forest and infrastructure conditions	Road-net density (truck roads) in metres per hectare
<u>Hilly terrain</u> Slopes of up to 40% with 60-80 m skid roads per ha	7 - 10
<u>Steep terrain</u> Using cable cranes	15 - 25
<u>Steep terrain</u> With intensive forest management	25 - 35

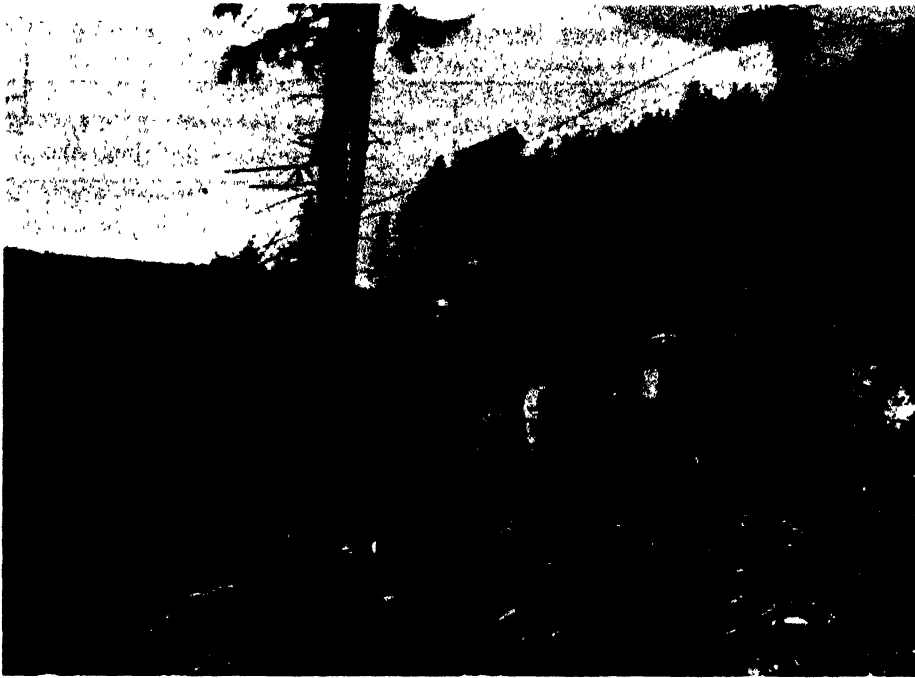
1.6 Integrated planning of road-nets and cable systems

In steep terrain 1/ the recommended road-net density is in the order of 20 m/ha, for reasons of economics, productivity, erosion problems, forest protection and so on. To obtain the most economic mix of road and off-road transport, the use of short-distance cable cranes, especially when mobile and radio-controlled, is a good complement to forest roads in mountainous areas. The maximum skidding distance of a short-distance cable crane is about 500 m 2/; the lateral skidding distance on both sides of the cable is about 20 m to 25 m. By using tractor-attached winches, wood can be skidded for up to 150 m uphill on to the road or landing.

In general, slopes over 70 percent have a tendency to landslides, especially after heavy rains and where soil and rock strata dip toward the valley; therefore, it is advisable to harvest such forest areas using long-distance cable-crane systems. Long-distance cable cranes (skyline length, generally more than 1 500 m) and those of medium range (skyline length, 700 m - 1 500 m) may substitute partly or entirely for roads so that they more or less take over the function of timber transport, especially in extreme situations.

1/ Slopes over 50%

2/ Some smaller systems up to 320 m



A forest area opened up by a combination of forest roads and cable cranes (Photo: R. Heinrich)

## 2. PARAMETERS INFLUENCING THE ECONOMICS OF ROADS

### 2.1 Climate

Road surveying, construction and maintenance should be limited to the dry period whenever possible because during the rains not only are erosion risks and dangers higher, but costs also increase considerably. During the rainy season in Bhutan, there is less forestry activity than in the drier periods. In general, about 150 - 180 actual working days/year can be counted on. The work is more affected by the intensity of precipitation within a certain period rather than by the yearly amount of rain. For instance some 150 - 300 mm of rain may fall in a couple of hours. Therefore, when roads in high-rainfall areas are planned, attention should be paid to exposure so that the roads will be dried by sunshine as quickly as possible.

It should be realized that due to the thinner air in high altitudes, labour productivity is less than in the lowlands and more frequent breaks are required to combat fatigue.

### 2.2 Terrain and soil

Road costs are heavily influenced by terrain, especially when the latter is broken by frequent gullies, creeks or small rivers. Careful attention should be paid to the stability of the terrain when a road is planned and laid out. Soft and wet areas should be avoided as much as possible. Often there is a scarcity of road-building material which has enough bearing capacity. Therefore, when the road line is surveyed, possible locations of natural gravel pits suitable for ballast material should be determined. Often the only suitable material is found in river beds or in the vicinity of rivers.



## 2.3 Stand and trees

The volume of logs to be harvested per unit area ( $\text{m}^3/\text{ha}$ ) is a decisive economic factor in the road layout, design and road-net density.

In general, the roundwood volumes per hectare are higher in coniferous forests than in tropical broadleaved forests. For the financial aspect, however, one would have to make comparisons from case to case.

If one assumed, for example, a roundwood removal of  $300 \text{ m}^3/\text{ha}$  and a road density of  $15 \text{ m}/\text{ha}$ , road cost per  $\text{m}^3$  would be equivalent to the cost of  $0.05 \text{ m}$  of road; however, if removal is only  $150 \text{ m}^3/\text{ha}$ , road cost per  $\text{m}^3$  would be equivalent to the cost of  $0.10 \text{ m}$  of road.

## 3. ROAD COST ESTIMATES

### 3.1 General

Machine costs in mechanized forest road construction may easily amount to 80 - 90 percent of the total road costs, thus construction activities must be carefully planned so as to use the equipment as efficiently as possible.

The skill of the forest engineer who locates and designs the road is critical to the overall construction costs.

Road construction costs vary considerably depending on the terrain and soil conditions, road standards, machine and labour costs, etc., as well as on the skill of the operators and labourers involved. However, since techniques are similar throughout the world, reasonable cost estimates can easily be derived once the main conditioning factors have been identified, by applying figures from similar road construction projects.

To facilitate the task of estimating and comparing forest road costs, it is advisable to break down labour and machine costs into their different elements.

The following breakdown is suggested:

- (i) Surveying, staking the alignment and clearing the way
- (ii) Formation of the road
- (iii) Rock blasting
- (iv) Drainage facilities (ditches, culverts)
- (v) Crushing gravel
- (vi) Gravelling, grading and compacting
- (vii) Construction and environment-protection works (bridges, retaining structures and soil stabilization works). The cost of constructing these is not dealt with in this paper.
- (viii) Miscellaneous work (such as transport, delivery and minor earthworks)
- (ix) Project servicing costs

Once the costs have been calculated for the different elements, unit costs (costs per m, per m<sup>3</sup>, per piece of construction work) should be developed to help in estimating costs in future road projects and for comparative purposes.

### 3.2 Staking, felling, forming, clearing and miscellaneous work 1/

In the case of a complete absence of cost data for forest road construction in tropical countries, FAO has developed a cost formula applicable to four different road standards and slopes, comprising the following work elements: felling, forming, clearing, and grading and miscellaneous work. These work elements represent a major share of the total road costs.

The equation reads as follows:

$$C_i = 370 + 27 \times SL + 1050 \times ST_i + 48 \times SL \times ST_i =$$

where  $C_i$  is the direct cost in US\$ per km for road standard  $i$  (supervision and overheads excluded), and where  $i$  is one of the four standards given in Table 3.

$SL$  = the inclination in percent of the major slopes (slopes longer than 50 m) of the hillsides

$ST_i$  = the values of the four road standards as taken from Table 3 below

0 = for trails for wheeled skidders and jeeps

1 = for secondary feeder roads

2 = for primary feeder roads

3 = for main and access roads

The above formula gives costs in US\$ as at 1977 and needs to be adjusted by some 30 percent to take inflationary cost rises in recent years into consideration. The formula applies for the following road widths including shoulders as shown in Table 3.

Table 3

#### VALUES USED FOR DIFFERENT ROAD STANDARDS

Standard	Description	Road width	Value ( $ST_i$ )
1	Access roads and main primary roads	10 to 12 m	3
2	Primary feeder roads	8 to 10 m	2
3	Secondary feeder roads	5 to 7 m	1
4	Skidding trails	3.5 to 4.5 m	0

1/ Miscellaneous work such as construction of sub-base culverts, and roadside drains.

It should be emphasized that this formula can serve only as an approximation in an estimate for the elements mentioned and it is not applicable at all in costing ridge roads.

Examples: direct construction costs calculated with the above-mentioned equation for a secondary feeder road on a 30% slope. The equation then reads:

$$C_3 = 370 + 27 \times 30 + 1050 \times 1 + 48 \times 30 \times 1 = 3\,670 \text{ US\$ per km.}$$

### 3.3 Gravelling

On soils with low bearing capacity, gravelling is required to make the road usable by heavy-duty vehicles on a year-round basis. Depending on carrying capacity of the underlying soils, the road width and the availability of appropriate gravel material, gravel costs can be up to 60 percent of the total costs and so become the most expensive item. Sometimes the distance to available sources of gravel can be an important factor in determining the viability or otherwise of forest projects in certain areas.

For easy reference an example of gravel costs from a developing country is given below for the following work inputs: taking the road material from a natural gravel pit, transporting, spreading and compacting it. A range of suitable costs is expressed in US\$ per m<sup>3</sup> of gravel. For a 4 m-wide road with 25 cm of gravel thickness, costs would also apply per m of forest road.

Table 4

#### ESTIMATED COSTS OF GRAVELLING A FOREST ROAD FROM A NATURAL GRAVEL PIT

Item	Cost in US\$/m <sup>3</sup> <u>1/</u>
Natural gravel at the pit	0.15 - 0.60
Loading of small quantities	1.10 - 2.10
Loading of large quantities	0.25 - 0.45
Transportation	1.70 per m <sup>3</sup> plus 0.10 per m <sup>3</sup> /km
Grading	0.20 - 0.30
Rolling	0.30 - 0.40

1/ Estimated costs expressed in US\$/m<sup>3</sup> as at 1980

When gravel is transported over a distance of 10 km, the total gravel costs per km may range from US\$ 4.70 to US\$ 6.55 per m<sup>3</sup> placed on the forest road, so that the cost of a 25-cm gravel surface on a 4 m-wide forest road would be US\$ 4 700 to US\$ 6 550 per km.



Proper planning, design and construction result in forest access roads which are important links between the public roads and the main forest roads

(Photo: R. Heinrich)

MACHINE INPUT IN FOREST ROAD CONSTRUCTION  
WITH SPECIAL EMPHASIS ON ROCK BLASTING IN MOUNTAINOUS AREAS

by

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1. INTRODUCTION

Modern forest road construction in Austria started more than 30 years ago to open forests on hillsides and in mountainous areas for management purposes. Since then, machine input has greatly increased, so that today there is a very high degree of mechanization in forest road construction in Austria. In the early days of mechanized road construction, angledozer left over from the second world war were used as foresters saw the advantages of using them. This innovation required new methods of road planning, appropriate to the enormous construction capacity of the machines.

2. DEVELOPMENT OF FOREST ROAD CONSTRUCTION

At first, small or medium-sized angledozer (8-10 t) were used for road formation, for excavation of the gravel needed for surfacing, and for rough shaping. Battering, constructing culverts, digging drains, and loading surfacing material for the road-bed still required manual labour. Material had to be moved by horse-drawn carts or farm tractors equipped with trailers. The equipment and road construction crew consisted of an angledozer and driver, up to 20 unskilled workers, a number of carts and farm tractors and, in rocky terrain, one or two compressors operating pneumatic drills. Nowadays, economic considerations require faster road construction techniques to open up mountain forests. With the advance into increasingly difficult terrain and lack of manual labour caused by migration to industrial zones, a high degree of mechanization in road construction methods is essential. As a matter of fact, equipment costs now amount to about 95 percent of the total road construction cost as compared with 50 percent a few years ago.

3. ROAD CONSTRUCTION MACHINE INPUT IN DIFFERENT TERRAIN CONDITIONS  
IN AUSTRIA

At present in Austria various types of specialized machines are used for road construction, depending on the terrain and geological factors as shown below:

Situation A

Terrain conditions not difficult, slopes not too steep and with a low rock component:

Angledozer	16 t, 120 kw	Formation, battering
Light excavator	7 t, 50 kw	Roadside drains, small culverts
Grader	12 t, 100 kw	Drains (V-section), shaping
Foreman or skilled worker		Managing work and equipment
		Blasting operations
Unskilled workers	1 - 2	Drilling, assisting operators

If necessary:

Compressor, operating 1-2 pneumatic drills; air output 2-2.5 m <sup>3</sup> /min; 6 bar	0.8 t, 20 kw	Minor blasting operations
Heavy excavator (hydraulically run)	18 t, 50 kw	Big culverts, protective constructions consisting of large rocks

#### Situation B

Difficult terrain, steep and rocky slopes, hairpin bends required:

Heavy traxcavator	17 t, 110 kw	Formation, battering, filling and depositing blasted debris
Light excavator	7 t, 50 kw	Roadside drains, small culverts
Grader	12 t, 100 kw	Drains (V-section), shaping
Heavy excavator (hydraulically run)	18 t, 50 kw	Hairpin bends
Rock drill mounted on crawler tractor; air output 8.5 m <sup>3</sup> /min; 10 bar	15 t, 95 kw	Major blasting operations
Foreman		Managing work
Skilled worker (blaster)	1	Blasting, protective constructions
Unskilled workers	2 - 3	Drilling, assisting operators

#### Situation C

Conditions of terrain extremely dangerous because of slopes which are steep and formed by compact rock; therefore, a special construction method is required to avoid damage to stands, public and private facilities.

Heavy excavator (hydraulically run)	18 t, 50 kw	Formation by digging "catching" trenches, constructing dry walls of heavy boulders in order to retain the spoil from the higher slope and/or by loading dump trucks with the surplus of material
Rock drill (as above)		
Blaster	1	
Unskilled workers	1 - 2	
Dump trucks (if necessary)	25 t, 210 kw	Longitudinal transport
Grader	12 t, 100 kw	Shaping

# Situation D

For basing and surfacing of the forest road:

Heavy traxcavator or	17 t, 110 kw	(Loading and spreading rock
Heavy excavator (hydr.)	18 t, 50 kw	and gravel)
Dump trucks (3-axle)	25 t, 210 kw	Transporting
Traxcavator	11 t, 65 kw	Grading the base
Grader	10 t, 70 kw	Grading the surface
Vibratory roller	9 t, 95 kw	Achieving high-degree
		compaction of the road
Foreman		Managing work

## 4. ROAD CONSTRUCTION COSTS

Road construction costs vary considerably due to:

- variable conditions of soil, rock and slope
- variable conditions of the weather during construction periods
- the skill and the experience of the construction team including the management.

Situation		A	B	C	D
Output per construction day (10 h)	m	250-150	150-80	80-50	300-200
Cost per km	US\$ 1 000	5- 10	10-30	30-70	10- 25
		roadway 4 - 5 m			

Road construction costs are based on an average machine and worker's production output, as compiled from various road construction sites in Lower Austria during 1982.

	Weight (t)	Power (kw)	Costs (US\$/hr)
Angledozer	16	120	47.50
Traxcavator, heavy	17	110	45.80
(ditto) light	11	65	35.10
Excavator, heavy	18	50	38.20
(ditto) light	7	50	28.10
Grader	12	100	39.20
Roller	9	95	40.90
Compressor	0.8	20	9.40
Rock drill	15	95	50.30
Dump truck	25	210	37.10
Foreman			15.40
Blaster			14.20
Unskilled worker			3.20

## 5. CONCLUSIONS AND RECOMMENDATIONS

The use of traxcavators and excavators instead of angledozers in forest road construction has proved to be of great advantage in mountainous areas. If terrain conditions are difficult, filling and depositing of blasted debris can be carried out by these machines carefully enough to avoid damaging the environment. It should be emphasized that the forester who planned the road should also be responsible for supervising the construction.

To do a good job from both the economic and environmental points of view, the crew undertaking the work, consisting of a foreman, operators, skilled workers and a forester, must be a team of well-trained, coordinated and experienced men.

The training of this crew should be one of the main tasks of the forester responsible for supervising road construction activities. High efficiency and working speed may tempt the forester and his crew to use highly mechanized techniques which, if not properly applied, will cause serious damage to natural resources and the landscape. Therefore the crew should always bear in mind that road construction is not an end in itself. Its purpose, on the contrary, is to ensure proper forest operation on a continuous basis.



Tractor-mounted rock-drill used in mountain forest road construction (Photo: E. Pestal)



## COSTS AND PRODUCTION IN FOREST ROAD CONSTRUCTION

by

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### 1. INTRODUCTION

Modern forest roads are designed and dimensioned for use by heavy-duty trucks and trailers. In Austria, the maximum total weight of the loaded transport unit is 38 tons. Forest roads generally have one lane with lay-bys provided at intervals. The carriageway is usually 4 m wide, although curves are wider to accommodate the mountainside ditch. Required additional road width on curves is:

10 cm	for a radius of 100 m
20 cm	for a radius of 90 m
30 cm	for a radius of 80 m
40 cm	for a radius of 70 m
50 cm	for a radius of 60 m
65 cm	for a radius of 50 m
85 cm	for a radius of 40 m
125 cm	for a radius of 30 m
155 cm	for a radius of 20 m

The subgrade should be 5 - 8 m wide so that logs can be processed and stored alongside the surfaced road. For maintenance reasons (scouring) maximum gradients should not exceed 10%. The maximum adverse gradient for loaded transport units is 7%. The minimum gradient is 3 - 4% since potholes are likely to occur in the water-bound gravel pavement of roads with lower gradients. For aesthetic reasons curves are the best locations for gradient changes. Changes between gradients and countergradients are best placed at curves because water discharge is easier there.

The optimum road net density for modern timber harvesting methods is 20 - 30 m per hectare of woodland. The final density is decided at the initial planning stage, even if at the beginning only main opening-up routes are built. In principle, the ratio between metres and hectares depends on economic considerations. The profitability of a dense road net is reckoned by comparing higher construction and maintenance costs with savings in timber production. The optimum road density is reached just before construction and maintenance costs start to exceed savings in timber production. Although this might seem quite obvious, there are many examples of excessive road densities which cause total harvesting costs to increase.

### 2. CONSTRUCTION OF A SUBGRADE IN EARTHY TERRAIN

#### 2.1 Machines employed for construction of a subgrade in earthy terrain

In terrain conditions of average difficulty, the angledozer works most efficiently. It is employed for longitudinal and transverse levelling even for distances of up to 30 m and for operation in relatively soft terrain. The angledozer must be sufficiently powerful

(minimum weight 17 tons) to extract stumps and thus avoid blasting. Traxcavators are preferred for longitudinal levelling of more than 30 m and more solid terrain. These machines are well suited for earth movements over longer distances; they consume less energy, and are powerful enough for stump extraction, but they cannot be used in soft terrain. Crawler tractors are applicable only if longitudinal levelling is not required.

## 2.2 Construction work

To avoid delay, construction work should start as soon as the route is cleared of standing timber. If batters do not exceed 3 m excavation starts at road level and the machine works toward the batter. If batters of more than 3 m are constructed, work starts just below the intersection of batter line and slope and cutting is carried out in several sequences down to road level. Excavation work by crawler tractor almost always starts at road level, even if batters exceed 3 m.

## 2.3 Costs

In average terrain, the productivity of a traxcavator is about 20 m per machine working hour. Crawler tractors achieve 15 m an hour. Costs per metre are between AS 35 and AS 50 (US\$2.06 and \$2.94), excluding overheads.

## 3. CONSTRUCTION OF A SUBGRADE IN ROCKY TERRAIN

### 3.1 Machines used

#### 3.1.1 Drilling devices

Rock drills are usually mounted on wheeled or crawler tractors which also carry the compressor and hydraulic unit. At present, industry offers the following types of rock drills:

Internal drill hammer. Small masses are moved so energy consumption is relatively low. The drilling-hole depth has no influence on the drilling speed. Performance is rather moderate, 15 - 25 cm per minute. The drill-hole diameter is small. Internal hammer drills are technically simple and they are used for all types of rock. Their disadvantage is the low drilling speed which leaves excavation machines standing idle for long periods.

External hammer drill. Performance is very high, but substantial energy losses occur if working with compressed air. Therefore, energy consumption is high and performance decreases with rising drilling depth. Internal hammer drills always produce excessive drilling diameters of 85 mm so that blasting charges have to be enlarged. With external hammer drills, however, the hole diameter varies between 54 and 85 mm. The biggest advantage of the external hammer drill is high productivity so that the work of other road construction machinery is not unnecessarily delayed.

Revolving drill. This drill has a mechanical drive and air is used only for blowing out the spoil. Instead of hammering, it drills with a revolving bit which is driven into the rock under high pressure. The power requirement is the lowest of all rock drills. The speed is similar to external hammer drills, 80 - 120 cm/minute. Revolving drills are advisable only for non-abrasive rocks such as limestone and dolomite.

Hydraulic hammer drill. The speed of this drill is comparable to that of the external hammer drill and revolving drill. However, investment is high and technology is not yet fully developed. Servicing is complicated and the drilling column breaks more often than air-driven devices.

Hand-operated hammer drills. These are driven by compressor; 20 cm<sup>3</sup> of air are compressed to 6 - 7 bar a minute. A light compressed-air supply with connexions at intervals of 20 m is led to the worksite. Hammer-drill hoses are attached where required and the route is manually drilled piece by piece. A well-tested hammer drill is the BH 16. Drilling bits of the following dimensions are used:

80 cm	42 mm bit diameter
160 cm	40 mm bit diameter
240 cm	38 mm bit diameter
320 cm	36 mm bit diameter
400 cm	34 mm bit diameter
480 cm	32 mm bit diameter

### 3.1.2 Excavation machines

To clear blasting spoil, angledozers, traxcavators or excavators can be used. Angledozers are used only if the terrain is mainly earthy and blasting is required too rarely to justify the purchase of a special machine. Clearing blasted spoil by traxcavators is fastest; performance is very high. There are two disadvantages, however: the material of transverse levelling cannot be deposited on the lower slope which has already been substantially affected and the upper slope can be soundly secured only up to a height of 3 m. Therefore, shovel excavators are increasingly employed for clearance. The batter can be secured up to substantial height, transverse levelling does not affect the lower slope and excessive material can be transported along the road by trucks.

## 3.2 Construction work

### 3.2.1 Mounted rock-drill method

Drilling, blasting and clearing are alternating operations. Up to a batter height of 3 - 4 m a single horizontal hole is drilled at the height of the proposed road ditch. If the batter exceeds 3 - 4 m a second hole is drilled upward from the same starting point. The drilling depth is 15 m for straight road sections and 6 - 12 m for curves. The rock-drill device is removed from the area of blasting, the charge is filled in and ignited. The blasting agent should be powerful and water-resistant; fuses or electric detonators in combination with detonation cords are used for ignition. After blasting the excavation machine starts by clearing just enough of the spoil to provide sufficient space for the rock-drill. For one-lane roads three to five work sequences can be done in a 10-hour working day. Annual performance for this kind of road construction varies between 5 and 10 km depending on slope gradient and type of rock.

### 3.2.2 Hand-operated hammer drill method

The compressor is situated at the working end of the cleared subgrade. An air supply of 300 m is led from the compressor along the proposed route. Hand-operated hammer drills can be attached where required without moving the compressor. Drilling work continues for the whole day, in the evening the charges are blasted and on the following day the spoil is removed while drilling work continues. After the subgrade is cleared, the compressor is pulled forward and hammer drills are reconnected to the air supply.

Changing the compressor's position and readjusting the air supply takes half an hour. This kind of work sequence leads to much faster construction although vertical head drilling requires higher quantities of blasting agent and higher wage costs. The big advantage of this method is finer blasting spoil (because of millisecond detonation) and considerably less damage.

### 3.2.3 Costs

Costs of mounted rock-drill method, excluding overheads:

- Machine costs	AS 120/linear m
- Wage costs at idle times of machine	AS 44/linear m
- Blasting and detonating agents	AS 110/linear m
	AS 274/linear m (US\$16.18)

Costs of hand-operated hammer drill method, excluding overheads:

- Machine costs	AS 110/linear m
- Wage costs	AS 150/linear m
- Blasting and detonating agents	AS 130/linear m
	AS 390/linear m (US\$22.95)

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## 4. SURFACING

### 4.1 Machines required for surfacing

The material used for surfacing a forest road must be wear-and-tear resistant and of mixed geological composition. It is either gravel found naturally or rock obtained by blasting. Blasted rock is reduced to suitable size by using mobile rock crushers with a minimum mouth opening of 1 m<sup>2</sup>. Gravel with an undesirable size distribution is passed through a mobile sorting plant with an exchangeable sieves so that the appropriate sieve size can be chosen. From rock crushers or sorting plants, surfacing material is loaded on to trucks or into bins using powerful wheeled loaders or excavators such as the Cat 950 or the Cat 225. To cope with the heavy loads, trucks must have three axles but all-wheel drive is not necessary for the gradients quoted in the chapter on planning. Loads are dumped on the road by tilting the truck platform to the sides or rear or by using a device which dumps only to the rear. Light graders with hydraulically adjustable blades are used to level and shape the surface.

### 4.2 Construction work

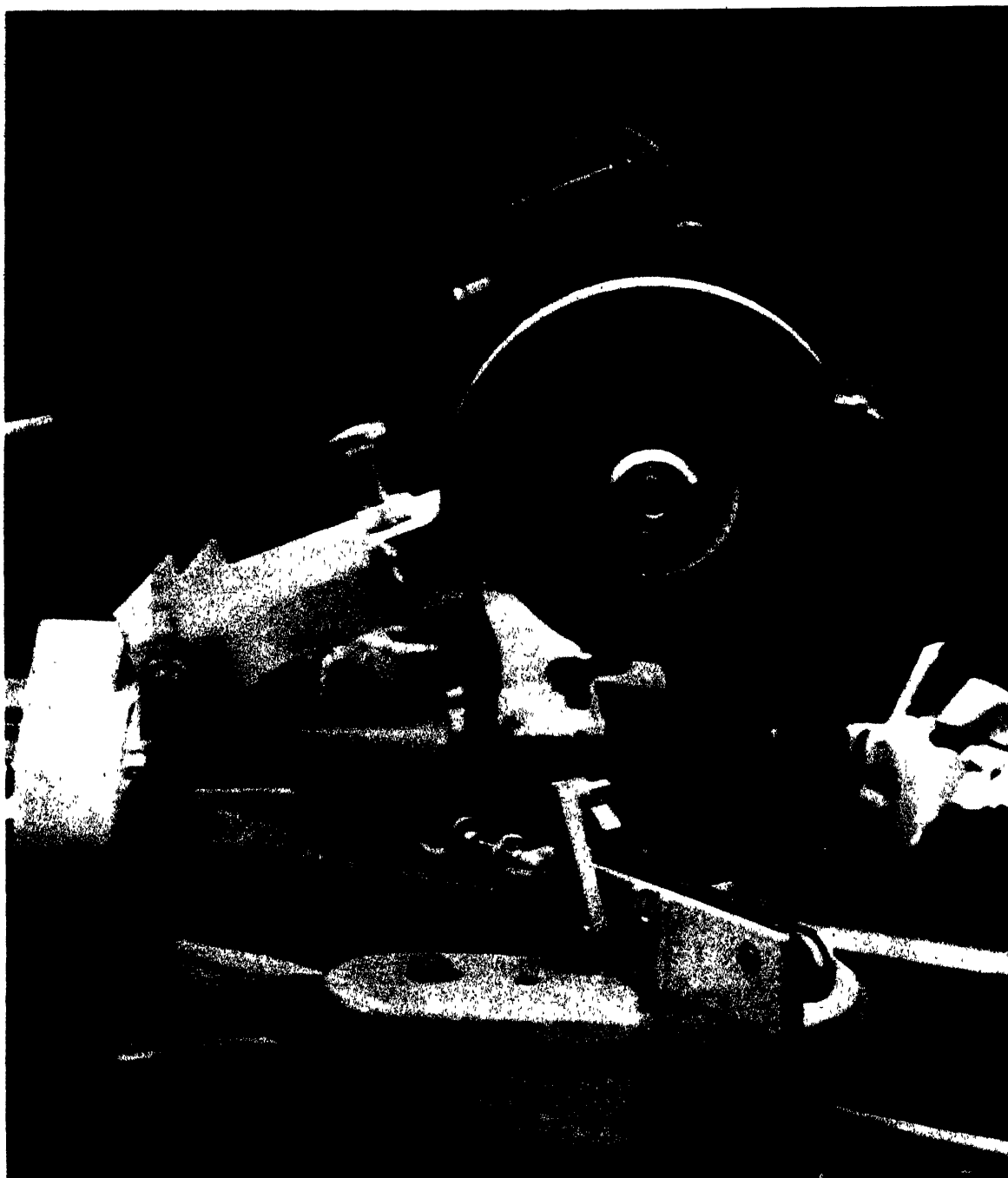
If there is no natural gravel pit, surfacing material is obtained by blasting. Holes are drilled into the rock by mounted rock-drills according to an accurate drilling plan. They are charged and blasted by millisecond detonation. If required, the blasting spoil is broken or sorted. For the work sequences loading - transport on to subgrade - levelling and shaping, the number of trucks used must be sufficient to arrive at the drilling site at intervals of 10 minutes.

#### 4.3 Costs

Costs depend on the type of subgrade and the transport distance from the gravel pit. Another decisive factor is the use of naturally found material or rock which has to be blasted, crushed and sorted. Costs therefore vary between AS 100 and AS 900 (US\$5.88 and \$52.94) per metre of road.



Blasted material deposited on a steep slope  
(Photo: M. Jedlitschka)



Electrical chainsaw sharpening equipment

(Photo: T. Frisk)

## ROAD EMBANKMENT STABILIZATION WITH BIOLOGICAL AND ENGINEERING WORKS FOR FOREST ROADS

by

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### 1. INTRODUCTION

The basic requirement for modern forest management, especially wood harvesting, is a well-planned and well-designed forest road network. When roads are planned and located careful attention must be paid to avoiding or reducing the impact of erosion, particularly in steep terrain.

Areas particularly susceptible to erosion problems such as very steep slopes with easily erodable soils and rock strata dipping toward the slope should be avoided as far as possible.

Erosion caused by road construction and soil disturbance can be avoided by using biological means and/or engineering structures. Slope and gully erosion adjacent to the road is very often a result of overgrazing and denudation of hills, which expose the soil to wind and rain and endanger the road structure. Erosion often occurs on cuts and embankments, on the outlets of cross drains and water flows, and on the surface of the road itself.

This paper describes briefly how to plan and survey forest roads to meet technical standards and to keep soil disturbance by cuts and fills to a minimum in order to minimize erosion.

Revegetation practices are described in detail to demonstrate how mass slope failures can be controlled. Simple and inexpensive types of engineering structures are also presented.

### 2. ROAD PLANNING, SURVEYING AND DESIGN

To plan a road alignment, good topographical maps, preferably with a scale not larger than 1:10 000, are necessary. The main areas to be served by the forest road should be determined and marked on the map. If no good contour maps are available, then extensive field work is required to measure the elevations of all main points and to record detailed terrain features. For low-cost roads such as forest roads, the survey method differs significantly from the classical engineering surveying methods. In a reconnaissance survey the main points which have first been marked on the map should be found in the field, and elevation measurements should be taken and recorded. The survey of the road itself consists of taking measurements between the points determined by the geometrical requirements of the road, which are dependent on its standard. Distances and vertical and horizontal angles are measured at each point by means of tape measure, clinometer and hand compass. It is advisable to measure the road line back and forth to have a control measurement and to exclude errors in readings. This simple surveying method has proved to be very efficient and sufficiently accurate for low-cost roads.

In steep and difficult terrain it is a great advantage to use this simple method, as it would be quite costly and time-consuming to survey with a theodolite. When you are surveying forest roads you should bear it in mind that road excavation volumes and fills should be balanced to achieve minimum soil disturbance. On slopes steeper than 70 percent it is advisable to construct full bench roads. It may often be necessary to construct retaining walls made of rock masonry, logs or gabions to reduce cut and fill soil disturbances further, especially on steep and unstable slopes. In such places, mid-slope location of roads should be avoided. In general, road gradients should not be more than 10 percent although in exceptional cases, and over short distances, 12 percent may be acceptable. In areas with high precipitation, water run-off on the soil surface is considerable and on roads with steep gradients adequate drainage facilities such as ditches, drains, culverts, fords and bridges are required.

In addition, under certain conditions it is advisable to tilt the road surface about 3 percent toward the downhill slope. This is best applied to full bench-construction roads. Outward sloping of the road surface has the advantage that rainwater drains off laterally, so that the quantity of water accumulated in cross drains, open top culverts and sub-base culverts is less, and the risk of erosion is reduced. However, outward sloping should not be applied on clayey road surfaces as they become extremely slippery when wet, nor on slope fills, especially if these are not protected by vegetative cover.

On inward-sloping roads, the road surface water drains toward the slope, where a mountainside ditch, preferably paved, carries it to culverts which transfer it to the downhill side of the road.

Culverts should be protected by head walls; they should be sufficient in number to prevent erosion problems in the ditches as well as in the area below the culvert outlet. They should be placed safely in the road sub-base. (The compacted layer above a culvert should be equal to the diameter of the culvert, and at least 50 cm so that the culvert is not destroyed by traffic.)

Depending on the amount of debris, 30-60 cm-diameter precast concrete culverts usually give satisfactory results. If larger diameters are required, corrugated steel culverts should be used; they are easily transported and set up at the construction site - but they are more expensive. Another way to avoid cross culverts of larger diameter is to install two parallel pipes.

The gradient of the piped culvert should be not less than 3 percent and not more than 6 percent because both slow and fast running water has a negative effect on the protective structures of culverts.

Special attention should be paid to the surfacing of the road. A suitable mixture to be used as surfacing material consists of sieving grain 1/ and sedimentation grain sizes, so that there are as few spaces as possible between the large grains.

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1/ Sieve grain sizes are from 0.06 to 60 mm.



### 3. SLOPE PROTECTION AND STABILIZATION

It is of primary importance to determine the factors influencing slope instability so as to design appropriate control and rehabilitation measures. Very often a single measure may achieve the desired results but sometimes it may be necessary to combine measures to restore stability. For instance, on seepage slopes it may be necessary only to drain off the water with open ditches or stone-filled drains. In other places, the slope may also have to be revegetated in order to fix the surface. Where revegetation takes a long time, a retaining wall may be required. In a mountain road project in the USA (Idaho) it was noted that 80 percent of the surface erosion occurred within one year of the disturbance: thus it is important to stabilize slopes shortly after road construction.

#### 3.1 Slope drainage

The simplest method to drain springs and surface water safely is to use an open ditch or a system of open ditches. The main ditch is located in the direction of the slope gradient; secondary or lateral ditches are laid out in a fishbone pattern. Water should be collected as close as possible to its point of origin and should be channelled safely to the road ditch, culvert or any other water course nearby. In areas where there are steep gradients and large amounts of water run-off, pitched ditches may be required. The excavation of ditches should start at their lowest point so that the accumulating water may drain immediately. A very effective method of draining off subsurface water is by means of covered drains. On cut slopes these drains may also act as a type of retaining structure if made in a Y or arch shape, thus further increasing slope stability. The most common types are stone- or gravel-filled drains with or without pipes.

To check the efficiency of drains and for maintenance purposes, it is advisable to have a standing pipe at the junction of the main and secondary drains. Pipes may be made of concrete, brick or PVC 1/ material. Excavation of the drains should start at the lowest point, while pipe-laying starts at the top. The pipes should be placed as close to each other as possible, and they should be laid in watertight soils so that maximum drainage can be achieved. Piped drains are the most efficient and their effectiveness is long-lasting; however, they are more expensive and often not available. Normal stone drains may silt up after some time, therefore it is advisable to form a drainage channel of stones or put a bundle of brushwood at the bottom of the drain. The top may be covered with a layer of grass to prevent siltation more effectively.

Besides effectively stabilizing fill and cut slopes, drains may be very useful behind retaining walls.

#### 3.2 Revegetation of road embankment and slopes

Well-known revegetation measures for stabilization of cut and fill slopes may be grouped as follows:

- i) Seeding, grass turfing and mulching to obtain a grass cover;
- ii) Contour wattling, wickerwork fencing, contour planting and fascines to obtain shrub vegetation;
- iii) Reforestation with pioneer plants.

1/ Poly-vinyl chloride

### 3.2.1 Seeding

Very often before grass seed is sown on barren slopes, soil and site preparation such as shaping the slope, spreading humus and applying fertilizer may be required. The seeds may be sown either over the entire area, in rows or only in certain places. To seed an area of 100 m<sup>2</sup>, about 3 kg of grass seed is needed. It is an advantage to have legume seeds mixed with the grass as they are nitrogen fixers. It will take half an hour to one working hour to seed 100 m<sup>2</sup>. A mixture of deep-rooted and flat-rooted, strong, quick-growing pioneer grasses will give the best results in fixing the soil.

### 3.2.2 Grass turfing

Regeneration of the slope may be achieved with turf. The grass sods should be placed on the slope when the surface is wet and during the vegetative period. Depending on the availability of sods, slopes may be covered entirely or only in strips. The latter method would require additional seeding. On very steep slopes it may be necessary to fix the sods to help them get a firm grip on the surface. This can be done by means of sticks prepared from branches, twigs or bamboo.

### 3.2.3 Mulching

Mulching is a quick method of regaining grass cover on sterile, bare soils. This method of revegetation requires a layer of straw, wood fibre or other organic material which is spread on the soil. Seeds and fertilizers are added and finally the layer of mulching is fixed by spraying a cold asphalt suspension. The advantage of mulching is that the grass cover comes up within a relatively short time because the mulching creates a favourable microclimate and reduces the water loss from soil, the surface temperature and soil crust formation. It also prevents seeds from rolling or being washed down the hill and preserves the fertilizer. In the USA and Japan machines (hydro-seeders) have been developed which can spray the mixture of mulching material, water and an adhesive as well as seeds and fertilizers on to the slope in one operation.

In the alpine region of Central Europe, revegetation by mulching has been successfully used with the following method of application: the slope is covered by a layer of straw (2-4 tons/ha), which is spread by hand, using a ladder placed on the slope. Seed and fertilizer are spread by hand, again using a ladder. Seeds and fertilizer fall through the straw layer on to the soil. To fix the straw layer on the slope surface, an asphalt suspension of 50 percent asphalt in water is diluted to a 25 percent solution which is applied to the straw by means of a portable sprayer on a back-pack. About 0.5 litres of asphalt suspension per m<sup>2</sup> is applied. Spraying cannot be carried out during heavy rain and wind. Normally it is two to three hours after spraying before the mulch is fixed in position. By the time the asphalt suspension covering the straw layer has disintegrated the grass is usually well established.

#### 3.2.4 Contour wattling

Contour wattling, also called wattling and staking, is one method of establishing brush vegetation on steep slopes where a grass cover alone would not be strong enough to stabilize the soil. The slope is subdivided with dense brush rows and, if necessary, grass is seeded between the rows for additional soil fixation. Before wattling and staking is started preparatory work on the slope should be carried out by levelling small gullies and removing obstacles such as big loose boulders and branches. Then stakes should be driven in along the contours at fixed distances from each other, within the contour line as well as from row to row. It is desirable that every fourth stake should be one that can sprout. Staking should be started from the lowest part of the slope, moving uphill. Trenches should be dug just above the stakes and wattling consisting of green twigs and branches should be put in the trench, overlapping each other. Part of the twigs and branches should protrude above the surface to prevent soil from moving down the slope. The soil dug out is used to cover the lower contour wattling. A hectare requires about 17 000 stakes. Some technical data are given below, as well as production data of an example of contour wattling carried out in Jamaica under the supervision of Mr. Sheng, FAO Watershed Management Officer. Stakes sharpened at the bottom, 1 - 1.2 m long and with a diameter of about 5 cm were driven into the soil with a row interval of 1.2 m and a distance of 0.50 m from each other. About 15 cm of the stake was left above the soil surface. Contour trenches 20 cm wide and 25 cm deep were dug and bundles of wattling 13 cm in diameter and 3 m long were laid in the trenches. Six labourers of the ten-man working crew staked; two trenched and covered wattles; and two were used for transport and other duties. Such a team can complete up to 250 m<sup>2</sup> of wattling a day.

Another example where cuttings of several species were tested by Mr. Tautscher, FAO, was in Nepal. Species found to be most suitable were Salix tetrasperma, Salix vallichiana and Viburnum.

#### 3.2.5 Wickerwork fencing

This system is similar to the one described above and is widely used in the alpine regions of Central Europe. The difference is that the growing material is not buried in the soil in bundles, but is placed around the stakes like a fence with only the ends of the twigs in the soil.

Stakes 1-2 m long and with diameters of 5-10 cm are driven into the soil at 40-50 cm intervals. The rows need not necessarily follow the contour lines; good results have been achieved with rows at an angle of 45° forming rhomboid shapes with sides 1.5 - 4 m long. The stakes should be buried for three-quarters to two-thirds of their length. The spacing of the rows depends on the gradient of the slope and soil. Normally they are 1-4 m apart, laid out parallel. In alpine regions good results have been achieved using Salix spp. and Alnus spp. as growing material.

### 3.2.6 Contour planting (cordons)

Growing plant material 0.9 to 1.5 m long is placed in horizontal cross layers in the contour terraces. Terrace digging starts from the bottom of the slope and proceeds toward the top. The lower cross layers of planting material are covered with soil obtained from the excavation of the upper terrace. The spacing of the terraces depends on the gradient and the soil; it may be up to 3 m. The width of the terrace should be 0.5 - 0.6 m. Cordon layers may either follow the contour in a continuous line or be broken say to 5 m, and their ends overlap each other as the cordons progress up the hill. Using the row spacing indicated above, 3 500 to 5 000 cordons per hectare would be required.

### 3.2.7 Fascines

The technique is similar to the one used in contour planting but differs in that instead of cross layers, brushwood is laid in the terraces. This can be mixed with cuttings to achieve a green brush row. Between the brush rows slips or seedlings are planted. Terraces should have a gradient of 20 to 25 percent toward the slope, with a width of 0.6 - 1.2 m. The brushwood and cuttings should be about 20 cm longer than the width of the terrace.

### 3.2.8 Reforestation

Revegetation work should be carried out with pioneer plants to stabilize slopes subject to landslides, or as a preventive erosion control measure on severely degraded slopes. In alpine regions pioneer plants such as Alnus, Betula, Fraxinus and Prunus have proved to be most successful as far as their survival rate on eroded slopes is concerned. When plants for use as slope stabilizers are considered it should be borne in mind that they must have strong deep roots to bind as much soil as possible. Wherever possible it is desirable to select for the afforestation of bare slopes species which can be used as fodder or fuelwood trees, since there is a desperate need for such trees in many developing countries.

## 4. STABILIZATION OF DRAINAGE CHANNELS

Unprotected drainage channels which cross roads are very often the source of major erosion problems. Erosion occurs mainly on unprotected outlets of the drainage where runoff water frequently develops gullies. This can cause landslides and damage the road structure. Water drainage outlets and channels can best be protected by surfacing the soil with dry stones or cement-bonded stones. In channels with steep gradients, it is advisable to have some stones cemented above the bed to reduce water velocity and erosion.

A cheaper way of stabilizing channels and the outlets of drainage pipes is to provide rock riprap which in many cases gives satisfactory results.

To protect bridges, culverts and fords, structures such as rock riprap, dry stone or cement-stone retaining walls, or where applicable, wooden protective structures, may suffice. Very often revegetating the slopes of drainage channels gives satisfactory protection.

## 5. PROTECTING SLOPES WITH ENGINEERING STRUCTURES

Simple engineering works for forest road construction, such as dry stone structures, gabions, log crib revetments and timber retaining walls, have proved useful in many countries. They are inexpensive and easily constructed at the site using local material. As cement is often difficult to get or is not available in remote areas of developing countries, transport costs are high and skilled masonry labourers scarce, in this paper the main emphasis has been placed on dry stone structures and timber construction works.

### 5.1 Stone arches

Stones in the form of arches are placed in the soil of cut slopes. The width of such arches may be 0.60 to 1.20 m and they may be up to 1 m in depth. In between and above the arches, cuttings of Salix spp. may be planted for additional stabilization.

### 5.2 Dry stone retaining walls

Stones 20 to 30 cm in size are placed next to each other into the surface of the slope. In this work 2.5 - 4 m<sup>2</sup> per man/day may be achieved. Provision has to be made for obtaining and transporting the stones.

### 5.3 Gabions

Gabions are stone structures which are normally set up by hand and covered with wire mesh to keep them together.

The advantages of gabions are the following:

- i) Construction is simple. With proper supervision, unskilled labourers can set them up;
- ii) The cost is low;
- iii) Stone material which is available in many places at or near the construction site can be used;
- iv) Only wire mesh or wire needs to be purchased and transported to the site;
- v) Construction time is short;
- vi) They are very durable. In comparison with cement masonry walls, they are more resistant to mass movement without breaking, because they are flexible;
- vii) Water drains off easily, so the shear strength of the soil is increased and the hazard of slope erosion is reduced;
- viii) Grass grows in between the stones sooner or later, thus making the gabions even more stable and integrating them into the environment.

In Nepal the gabion cost amounted to some 140 rupees or US\$ 11.24 per m<sup>3</sup> constructed

Basic data used in the cost estimate were as follows:

Labour wages (average)	= 12 rupees per working day
Salary of foreman	= 500 rupees per month



Construction of a retaining wall consisting of rock boulders placed into the cut slope by excavator (Photo: O. Sedlak)



Destroyed retaining wall efficiently replaced by gabions  
(Photo: R. Heinrich)

Average construction output per m<sup>3</sup> of gabion was 1.9 man-days, which included preparing the wire mesh, collecting stones near the construction site, transporting and setting up the stones, forming the construction, as well filling in with rock.

Cost of wire per m <sup>3</sup> of gabion, including transport and tax	= 110 rupees
Direct cost per m <sup>3</sup> of gabion	
Labour (1.9 man-days)	22.8
Supervision	4.0
Hand tools	2.0
Wire	<u>110.0</u>
Total	138.0 rupees

#### 5.4 Log crib revetments

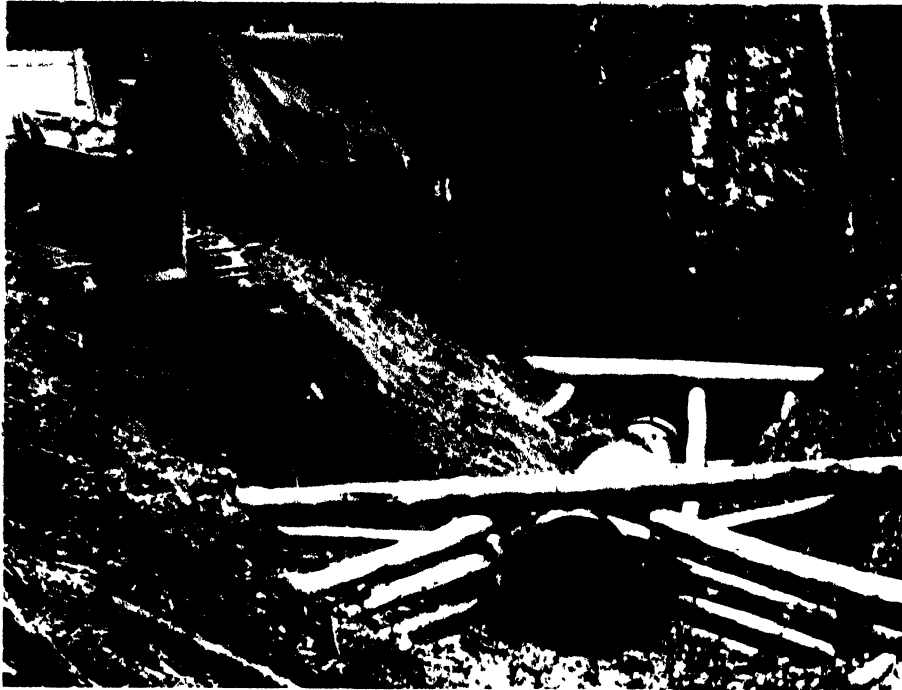
These structures may be of use where wood is easily available and where there is no adequate stone material or where the cost of stone structures is excessively high. Log crib revetments are made of roundwood and consist of logs laid parallel to the slope and cross layers which fix the structures into the subsoil of the slope. The cross layers should have a spacing of 1 - 2 m. Between the log layers, stone fill and growing material may be placed to protect the road from falls of stones and earth. Log layers and the ends of the cross logs must either be fixed by spikes or notched to fit into each other. In steeply sloping areas, it is advisable to construct a cage (crib) consisting of front, back and cross layers of logs, which would be more resistant to slope movement than inflexible masonry structures. Other advantages of log crib revetments are that they can be set up in a short time, they are cheap and local tree species can be used. Their disadvantage is that they have a limited life, generally 10 - 15 years; however, it may be expected that by that time treated slopes will have been stabilized.

#### 5.5 Timber retaining walls

This simple type of structure to protect slopes from erosion consists of stakes driven into the subsurface of the slope with timber nailed on to them on the upper side. They are placed near the road and also if necessary higher up along the contour lines of the cut slope.

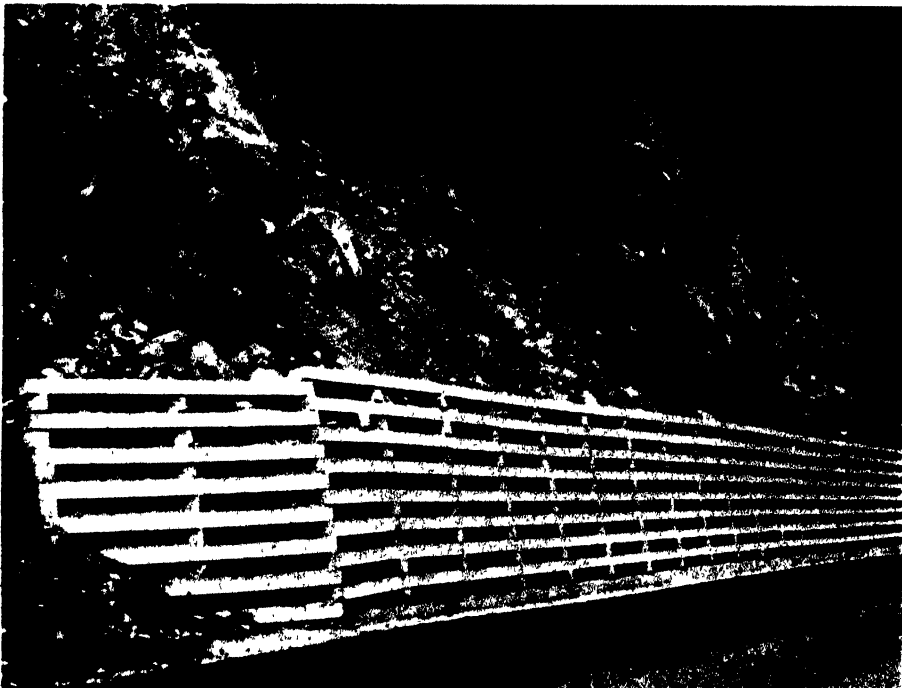
#### 5.6 Precast concrete crib revetment

These structures have been developed for areas where neither stone nor timber is economically available. Concrete beams of 250 cm x 12.5 cm x 12.5 cm, weighing about 90 kg, and crossbeams of 125 cm x 12.5 cm x 12.5 cm, weighing about 45 kg, are used. This example is mentioned only to give a more complete picture of the development in this sector of construction. At present their application may not be economically feasible in many developing countries, except for locations close to a source of cement.



A gully being filled by traxcavator, concrete culvert and supporting roundwood construction laid so as to guarantee natural waterflow

(Photo: FAO)



Concrete crib revetment consisting of precast concrete beams

(Photo: E. Pestal)



## 6. PROTECTION OF ROAD EMBANKMENTS AGAINST TORRENTIAL WATERFLOWS

Roads may be damaged when they are located along or across torrents. Erosion caused by the force of the running water may endanger or destroy the banks or embankments of roads or the road itself by scouring and erosion of the toe of torrent banks. At crossings of torrents or gullies, the road may become blocked by sediment and debris or destroyed by downhill mass movements. Measures to control erosion caused by torrents include reducing the velocity of the water by engineering structures and rehabilitating slopes of the gully or torrent banks. Thus, a combination of biological and structural bank stabilization, as well as construction of check-dams, or sills and check-dams, may be required to protect the road fully from erosion and sedimentation.

### 6.1 Embankments

Embankments may be constructed using various materials. The most common type is made of rocks. Stones protecting the toe and bottom of the channel should have a diameter of at least 0.5 m and those protecting the banks should be 0.3 m and above. If only smaller stones are available, paving with stones covered by a wire mesh is effective.

A quick method of stabilizing embankments is by putting boulders on the banks of the torrents - the structures called riprap. In torrential flows with great hazards of bed erosion and scouring, the paved toe may additionally be protected in the same way.

A combination of layers of boulders and layers of fascines with growing material may give good results, as the water velocity is reduced by the fascines on one side and the embankments are made more stable because of the vegetative cover. The cuttings should be planted into the subsoil about two-thirds of their length.

Boulders in combination with grass turfing, or grass turfing with brush and trees on the embankments, may provide good results in stabilizing embankments.

In areas where wood is available, log crib revetments with stone fill between the logs may be constructed. A layer of logs should be placed at the bottom of the revetment to prevent the fill material from being washed out of the structure. Bank revetments and retaining walls made of concrete are very effective; however, they are more costly than the structures mentioned above.

## 7. ROAD SURFACE PROTECTION

### 7.1 Open top culverts

An effective way to control road surface erosion is to put in open top culverts or simple earth cross-drains, which will lead the surface water from the road. Open top culverts can be made of steel, concrete, timber, roundwood or simply earth debris. Open top culverts must be placed into the road with a cross-gradient to make them self-cleaning. Normally a cross-gradient of 6 - 7% is sufficient.

The effectiveness of open top culverts depends largely on correct spacing and maintenance work (clearing of soil particles, leaves and twigs, etc.). Spacing depends mainly on the gradient of the road, amount of precipitation, steepness of terrain and soil conditions. In a watershed forest in steep terrain with high rainfall, Sessions (1974) proposed a spacing derived from the formula 800 divided by the gradient in percent. However, in areas with heavy rainfall and large catchment areas, a closer spacing (20 - 40 m), especially on roads with gradients of 9% or higher, may be required. The correct spacing of open top culverts must be decided through experience. The table below can be used as a guide.

SPACING OF OPEN TOP CULVERTS IN METRES

<u>Road gradient in percent</u>	<u>800 gradient in %</u>	<u>Suggested spacing in steep terrain with heavy rainfall</u>
5	160	80
6	130	65
7	114	55
8	100	45
9	88	40
10	80	35
11	72	30
12	66	20 to 30

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CASE STUDIES OF WOODEN AND CONCRETE CHECK-DAMS IN CONNEXION  
WITH FOREST ROADS

by

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INTRODUCTION

In mountainous and hilly terrain the road construction engineer is always faced with potential destruction of or damage to parts of the forest road net or installations (particularly bridges and culverts) in waterways and on unstable slopes.

Torrents are a main concern since floods may be intensive and occur suddenly and subsequent erosion is likely to cause substantial damage. Torrents are defined as natural waterways with small catchment areas and irregular and partly steep longitudinal sections, with extreme fluctuations in runoff and rapidly swelling flood peaks following heavy rainfall. As a result, there is substantial bed load transport and sedimentation.

The principal effects of most torrents are the following:

- Erosion of all forms - sheet, rill, gully, bed and lateral or bank erosion;
- Sedimentation in the torrent channel and in the neighbouring areas;
- Inundations, frequently as a result of, or intensified by, sedimentation in the torrent channel.

Damage or destruction can occur whenever a forest road leads along or cuts across a torrent channel.

The main causes of damage and destruction by torrents are as follows:

- (a) Lateral or bank erosion. In this case, the running water destroys banks and road embankments along the sides of waterways. The intensity of erosion increases with the depth and speed of the running water. Therefore the toe of banks and road embankments as well as the toe of protective structures (retaining walls, bank revetments, rip-raps and so forth) are particularly exposed to danger.
- (b) Bed or channel erosion. In this case, the running water deepens the bed of the channel. It endangers and destroys the toe of banks, road embankments and the base of protective structures as it is often accompanied by lateral erosion. The abutments of bridges are frequently endangered. If a bridge has a narrow span, this increases the velocity and the depth of water during heavy flows so that bed erosion is also increased.
- (c) Scouring at the downstream end of paved fords and culverts.

- (d) Erosion of the road surface or the entire road. This occurs when the cross-section of the channel is too small and floods overflow parts of the road. Frequently, the reduction of the cross-section is an artificial one. There are two main cases. The first is a consequence of road construction along a torrent channel where the valley is narrow and the slopes are steep. In this case, a part of the embankment is often in the channel. The second occurs when the span of a bridge or the diameter of a culvert is too small for flood peaks and bed loads, branches, trunks and so on are brought down during the flood.

The greatest damage and destruction to forest roads is caused by erosion. Therefore, the most important purpose of protective measures is to combat erosion.

#### PROTECTIVE MEASURES AND PROTECTIVE STRUCTURES

To prevent or reduce damage or destruction caused by torrents of unstable slopes, the roadbuilder may take two protective measures:

- (a) He may avoid the problem by constructing roads, bridges and culverts outside of danger areas whenever possible (passive protection);
- (b) He may protect roads and installations with appropriate structures (active protection).

The principal types of protective structure are the following:

- check-dams
- rip-rapping
- bank revetments
- retaining walls
- paved channels
- drains and ditches.

Check-dams are structures built across the stream. According to function, they are classified as follows:

- (i) Stabilization check-dams of up to 5 m or 6 m in height, and
- (ii) sediment storage check-dams of up to 15 m which retain sediment load, trunks, branches and other debris.

One of the most important objectives of stabilization dams is to stop channel-bed erosion. This always occurs between the abutments and downstream of a bridge. Another important function of this type of dam is to support the toe of steep slopes against undercutting by lateral erosion.

The simplest type of check-dam and therefore the type most frequently installed in forest road networks is the straight gravity check-dam.

### The straight gravity check-dam

The main parts of this type are:

- overflow section
- wing walls
- check-dam body
- foundation
- weep-holes

### Overflow section

For the overflow section or spillway, a trapezoidal shape is generally used. This is hydraulically better than a rectangular shape and corners are less exposed to damage from debris. The crest of the spillway (which is at the same time the cover and top of the check-dam body) should be very strong in order to resist wear from the bedload passing through. Depending on flow conditions and construction material, its width should be between 0.80 m and 1.50 m. The size of the overflow section depends on the runoff and its capacity -  $Q$  (required) - has to be equal to or bigger than the flood peak ( $HQ_n$ ) to be expected, i.e.  $Q$  (required)  $\geq HQ_n$ . To calculate the spillway capacity, there are two main methods:

- a) If the overflow section is about as wide as the upstream cross-section of the channel the formula applied for canal construction is used:

$$Q \text{ (required)} = F \times v$$

$Q$  (required): amount of water to run through overflow section in  $m^3/sec$

$F$  : area of the overflow section in  $m^2$

$v$  : velocity of passing water in  $m/sec$

The area  $F$  is calculated from the assumed dimensions of the overflow section.

The velocity can be calculated by means of the formula of Manning-Strickler:

$$v = K \times R^{2/3} \times J^{1/2}$$

$v$  : mean velocity of the water in  $m/sec$

$K$  : coefficient of roughness of the natural or construction material

$R$  : hydraulic radius,  $F/U$  in metres

$U$  : wetted perimeter in metres

$J$  : gradient of the channel expressed as a decimal fraction (for instance 0.05, if the gradient is 5%).

The coefficient of roughness depends on the material of which the channel is made and the following may be used:

$K = 20 - 30$  for natural torrent channels

$K = 30 - 40$  for channels paved with big stones

$K = 40 - 50$  for channels constructed of masonry

$K = 60 - 70$  for channels constructed of concrete

In both natural and artificial torrent channels experience has shown that the mean velocity is nearly always lower than 4  $m/sec$ , due to the bedload transport and the mixture of water and air which occurs at a velocity higher than 4  $m/sec$ .

- b) If the cross-section of the channel bed is considerably bigger than the planned overflow section, the Bergthaler formula, which accounts for complete fall-over, is used:

$$Q \text{ (required)} = \frac{2}{3} \alpha \times 4 \sqrt{2g \times h \left( b + \frac{4}{5} n \times h \right)}$$

Q (required): amount of water (m<sup>3</sup>/sec) to run through overflow section  
 $\alpha$  : discharge coefficient for sharp-edged crests 0.66  
h : height of overflow section in m  
g : acceleration due to gravity 9.81 m/sec<sup>2</sup>  
b : lower width of overflow section (crest width) in m  
n : factor for the abutment gradient of overflow section  
(e.g. n = 2 if gradient 1:2)

By using the given values the formula can be simplified as follows:

$$Q \text{ (required)} = 1.97 \times h^{3/2} (b + 0.8 n \times h)$$

### Wing walls

Wing walls have a gradient of 5 - 15 percent (the higher the gradient of the channel, the higher should be that of the wing walls) and should reach 1 - 2 m into the banks of the slopes, so that they provide supports for the dam and avoid erosion of the slope toe and flooding of the wings by excessive runoff.

Depth and width of the foundation must be determined: it must be deeper than the bottom of the scour (or pothole) below the check-dam. To calculate this depth, Schocklitsch's formula may be used:

$$TK = \frac{4.75}{d_{90}^{0.35}} \times H^{0.2} \times q^{0.57}$$

- TK : difference between water level downstream of the check-dam and the bottom of the scour, in metres  
 $d_{90}$  : diameter, which divides the particles of the soil in such a manner that 90% of the mass is smaller and 10% bigger than the diameter  $d_{90}$ , in millimetres  
H : difference between the water level upstream and downstream of the check-dam, in metres  
q : specific runoff in m<sup>3</sup>/sec; that is, the runoff which passes through a section of 1 m of the spillway.

To increase protection against scouring an allowance of 0.5 m is added to the scouring depth. The dam height HK (difference between the crest of the spillway and the base) is therefore expressed by the following formula, h being the underwater height:

$$HK = H + TK - h + 0.5 \text{ m}$$

The width of the foundation or base width is the result of statics calculations.

For check-dams with a cross-section like a trapezoid and with a height of up to 6 or 7 m, simple assumptions and simple formulae may be used. For larger dams (larger than approximately 8 m) built of concrete or masonry, Hoffmann's formula may be used:

$$D = 0.46 \times (HK + h)$$

For short check-dams (shorter than approximately 8 m), Kronfellner-Kraus's formula may be used:

$$D = 0.35 \times (HK + h)$$

D : base width in metres

HK : difference between the crest of the spillway and the base of the dam, in metres

h : depth of the spillway in metres

A more exact formula for straight gravity check-dams is as follows:

$$D = -\frac{K}{2} + \sqrt{\frac{5}{4} \times K^2 + \frac{T^2 \times W}{S}}$$

D : base width in metres

K : width of the spillway in metres

T : HK + h in metres

W : specific gravity of water in t/m<sup>3</sup>

S : specific gravity of the construction material in t/m<sup>3</sup>

This formula is used for dams such as higher sediment storage check-dams, where it is considered that hydrostatic pressure acts on the dam.

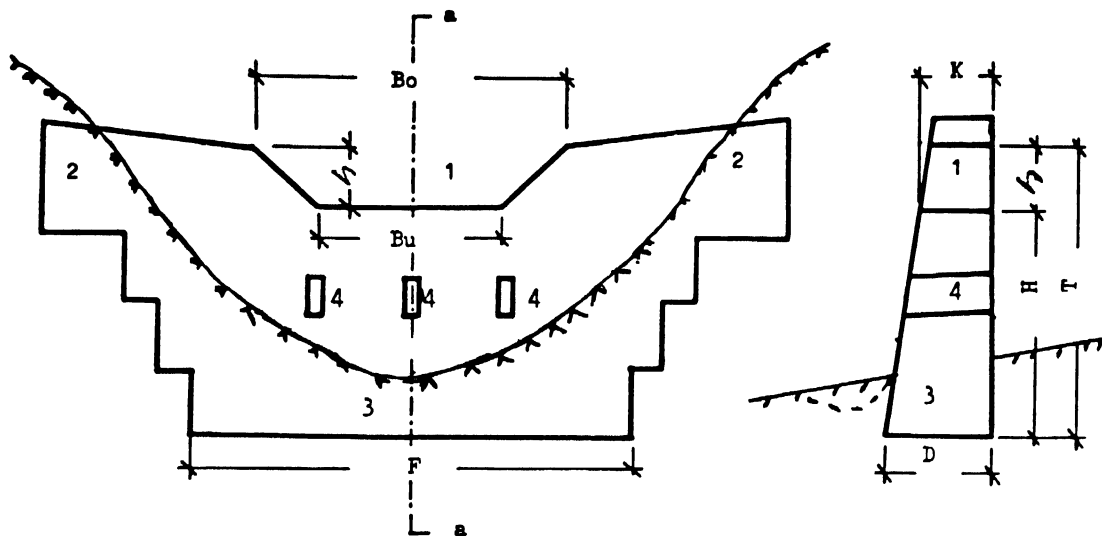
Table 1

WIDTH/HEIGHT OF STRAIGHT GRAVITY CHECK-DAMS

Base width D of dams built of concrete according to the exact formula for straight gravity check-dams depends on the dam height T if K = 1.0 m, S = 2.5 t/m<sup>3</sup>.

T (m)	D (m)
2	1.18
3	1.70
4	2.26
5	2.85
6	3.46

Fig. 1 PRINCIPAL PARTS OF A STRAIGHT GRAVITY CHECK-DAM

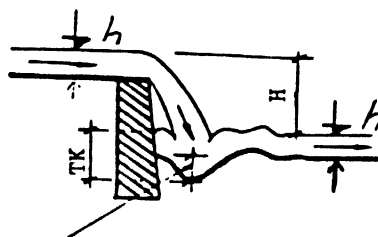


Front view

1. overflow section
2. wing walls
3. foundation
4. weep-holes

Cross-section a-a

Fig. 2 DEPTH OF SCOURING DOWNSTREAM OF A CHECK-DAM (CROSS-SECTION)



Depth of the pothole:  $TK - h$



Weep-holes. Check-dams made of concrete and masonry require weep-holes below the overflow sections. Their function is to drain the sediment mass thereby reducing the longitudinal pressure. Rock-filled crib check-dams and gabions are constructed without weep-holes since their bodies are naturally water-permeable.

#### Check-dam structures

The following types of check-dam are those most frequently used in forest road construction:

- concrete structures
- rock-filled log cribs
- gabion structures

#### Concrete structures

Construction material: concrete.

Production: components are thoroughly mixed in concrete mixers, wet concrete is chuted into forms and then tamped into place.

Check-dams for torrents require concrete of high quality to ensure a long life-span. For this reason, suitable construction material, trained workers and appropriate machinery must be available.

The overflow section - at least its lower part - is paved to protect the crest against channel erosion. For check-dams in forest road construction, concrete is used only if bridges are also made of concrete or reinforced concrete.

Advantages and disadvantages: advantages of high-quality concrete include long life-span, high resistance to wear and the possibility of producing complex shapes for arched dams and dams with special functions, at the construction site.

Disadvantages are high costs; the need for trained workers; and the need for specialized machines for mixing, transport and installation. Concrete dams are affected by slope movements.

Use: concrete check-dams are used mainly to protect costly structures also made of concrete.

#### Rock-filled log-crib structures

Required building material: round logs of various diameters, rocks and stones of various sizes, and big nails or round iron bars.

Method of construction: there are one-wall, two-wall and three-wall log-crib structures. The cribs may have only a front or downstream wall; a downstream and an upstream wall; or downstream, middle and upstream walls. The two-wall crib structure is most frequently used. The walls are based on a log substructure which is built first. It consists of eight round logs about 12 to 15 cm in diameter, which are nailed across two larger logs 20 to 25 cm in diameter. The distance between these two logs equals the length of the logs used in the substructure and is also equal to the thickness of the dam foundation. The log substructure has an upstream inclination of some 20 percent. One of its important functions is to avoid leakage of the crib content in case of scouring.

The lowest downstream and upstream wall layer is placed upon the base logs and joined by cross logs, called "ties". Ties are logs with a diameter of 15 - 18 cm spaced about 2 m apart. The space between the walls is filled with stones. The next wall layer is placed, fixed by ties and filled up with stones, and so on, until the required construction height is reached. The downstream wall is battered 1:5; the upstream wall is vertical.

For the overflow section big rocks are embedded between the wall layers.

The overflow section is built with a width of 1.30 m and requires particular attention to construction details: the joints between wall logs and ties are curved to fit tightly together. Logs used for timber crib check-dams should be treated to increase their life-span.

Advantages and disadvantages: Log crib structures have several important advantages. Local building materials can be used (roundwood, stones). Construction is relatively cheap since there are no transport costs. Machinery is not needed and workers' training is relatively easy. Structures are flexible and adjust to minor slope movements without being damaged or destroyed.

Their disadvantages are that timber construction material has a limited lifetime. It can be increased by treatment but this also increases costs. The stability of these structures is less as compared with concrete, so maximum construction height should be limited to some 4-5 m.

Use: Check-dams with log crib structures are used in forest road construction where small and less important structures need to be protected; where slope movements are expected; and where long life-span is not required.

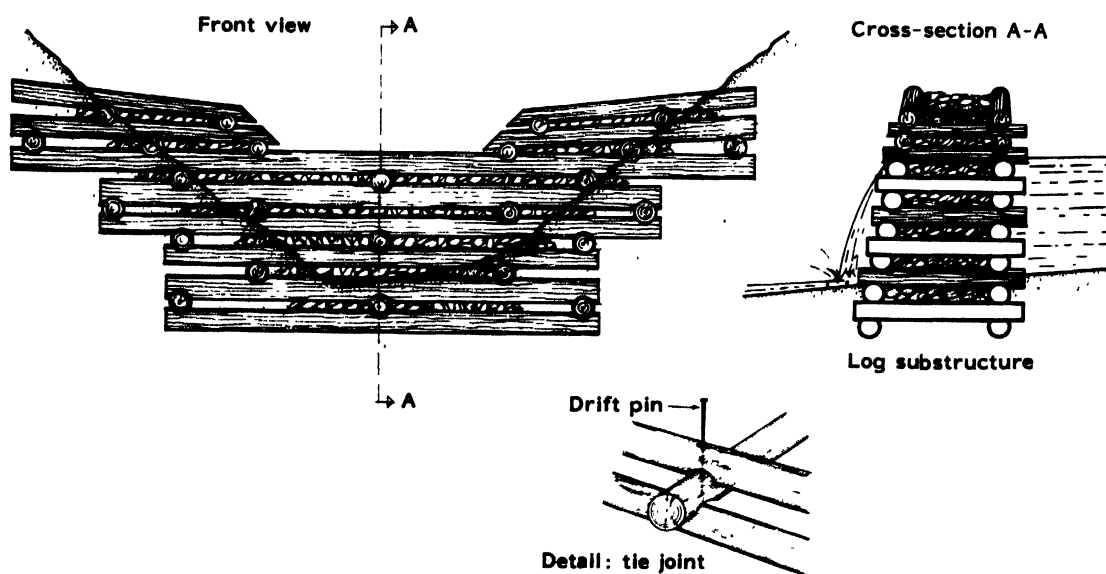


Fig. 8 DOUBLE-WALL ROCK-FILLED TIMBER  
CHECK-DAM UP TO 5 M WITH TRAPEZOID OVERFLOW SECTION

## STUDIES AND DESIGN OF PROTECTIVE MEASURES

Planning of simple protective measures generally includes two steps: study of data and detailed project planning.

1. General project planning will yield criteria for deciding whether protection measures are necessary, technically appropriate and economically justifiable.

The following steps are recommended:

- 1.1 Determination of sites where road sections or structures (bridges, culverts) are endangered by torrents. Lateral and bed erosion as well as landslides must be particularly considered;
- 1.2 Estimation of peak run-off, of erosion, of debris flow and landslide danger;
- 1.3 Estimation of probable cost of damage. The costs which would result from damage consist of:
  - cost of reconstruction of destroyed structures,
  - cost of clearance of structures from landslides,
  - cost due to interruption of traffic;
- 1.4 Designing necessary protective measures with due consideration to available construction material, personnel and machinery;
- 1.5 Simple surveys of torrent sections where protective structures are planned and collation and study of the data on the construction areas;
- 1.6 Estimation of costs of protective structures on the basis of a rough assumption of masses and prices;
- 1.7 Comparison of costs of protective measures and costs of potential future damage.

If the planner is certain that substantial damage will be caused by torrents or unstable slopes, he considers an alternative route to avoid danger zones. He decides whether such a route is feasible and technically appropriate and estimates its costs. This cost estimate is then compared with that of protective structures (see 1.6) in the original plan.

The cost comparison may show the following:

- (a) The alternative route is less costly;
- (b) Protective structures are cheapest;
- (c) The cost of damage is estimated to be low in comparison with costs of protective measures.

From such a cost comparison, a decision is taken between protective measures (alternative route or protective structure) and the risk of potential damage .

If the decision is in favour of protective structures the required detailed project plans are drawn up.

### Detailed project plan for a gravity check-dam

If the decision favours a check-dam, after the construction material has been decided on, the following steps are necessary for a detailed project plan:

- 1) determination of the site by field study;
- 2) collation of topographical information, of the channel and of structures to be protected, longitudinal gradients, cross-section of check-dam site and details of maps and plans;
- 3) survey of ruggedness of torrent channel, calculation of maximum flow velocity and geomorphological details of construction site to determine the scouring depth;
- 4) design of overflow section and calculation of the required flood discharge ( $Q$  required). The crest width depends on the channel width and is as large as possible without causing lateral erosion below the check-dam. The abutment gradient of the overflow section is usually chosen 1:1, i.e.  $n = 1$ ;
- 5) determination of wing wall gradient;
- 6) determination of dam height, i.e. vertical distance from crest to original channel base. Dams made of concrete have a maximum height of 5-6 m, rock-filled log crib dams and gabions are at most 3-4 m high. The dam height is frequently limited by height of banks. Further determining criteria are sedimentation, gradient and distance between check-dam and structure to be protected;
- 7) calculation of scouring depth;
- 8) determination of crest width. It is normally 0.8 - 1 m in concrete dams, 1 m in gabion dams and 1.3 m in rock-filled log crib dams;
- 9) calculation of foundation width;
- 10) graphic design of check-dam in front view and cross-section;
- 11) determination of masses;
- 12) determination of costs (unit costs and overall costs).

### CASE STUDY

#### 1. Assumptions

1.1 A torrent channel was crossed by an important forest road. Gradients downstream of the planned bridge would cause considerable soil erosion and damage would exceed cost of a check-dam to protect the bridge. The forest road was so important that the bridge was planned as a reinforced concrete structure. Qualified workers, required machinery and equipment, as well as material for the construction of a concrete gravity check-dam, were available. Roundwood and stones for the construction of a rock-filled log crib structure were also available.

1.2 Hydrological studies showed that a peak run-off of  $12 \text{ m}^3/\text{sec}$  was to be expected.

1.3 Longitudinal profiles of the construction sites of bridge and dam and cross-section of the site planned for the dam were surveyed using a clinometer, measuring tape and measuring rod and then depicted graphically (longitudinal profile at scale 1:200, cross-section at scale 1:100).

1.4 Collation of topographical data also included determining channel roughness with  $K = 40$  and grain diameter (for scouring estimate) with  $d_{90} = 100$  mm.

## 2. Calculations

### 2.1 Design of overflow section

The cross-section of the terrain permitted a crest width of 4 m ( $B_u = 4.0$  m). Since the overflow section did not narrow the natural channel substantially nor was a rapid sedimentation expected, the formula

$$Q = F \times V$$

was used for calculation.

To fulfill the consolidating function of the check-dam the crest was required to have a height which limited the gradient between dam and bridge to 2 percent.

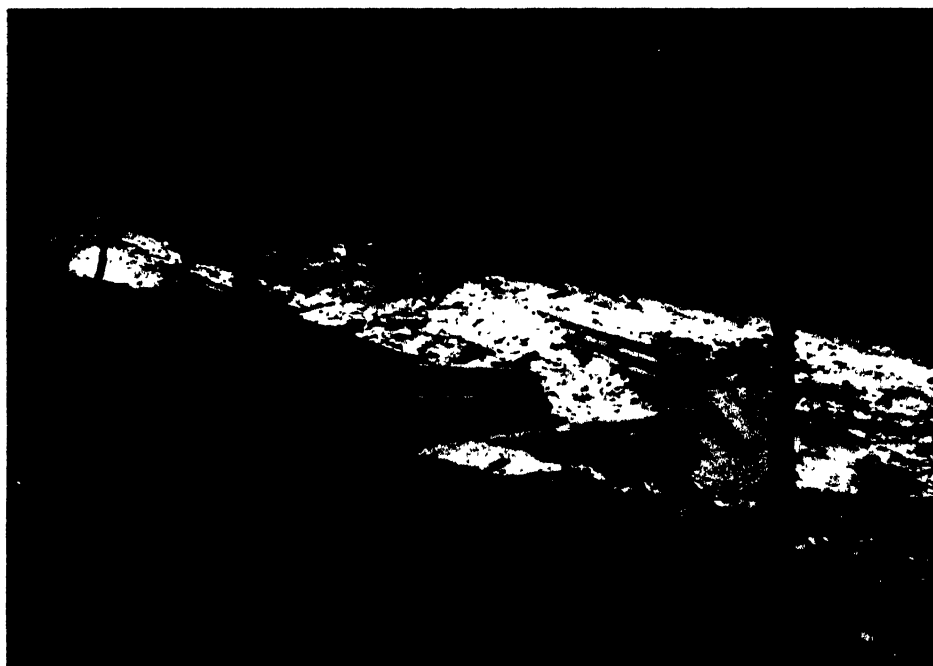
$$Q \text{ required} = 12 \text{ m}^3/\text{sec}$$

$$v = K \times R^{2/3} \times J^{1/2}$$

$$K = 40$$

$$R = \frac{F}{U}$$

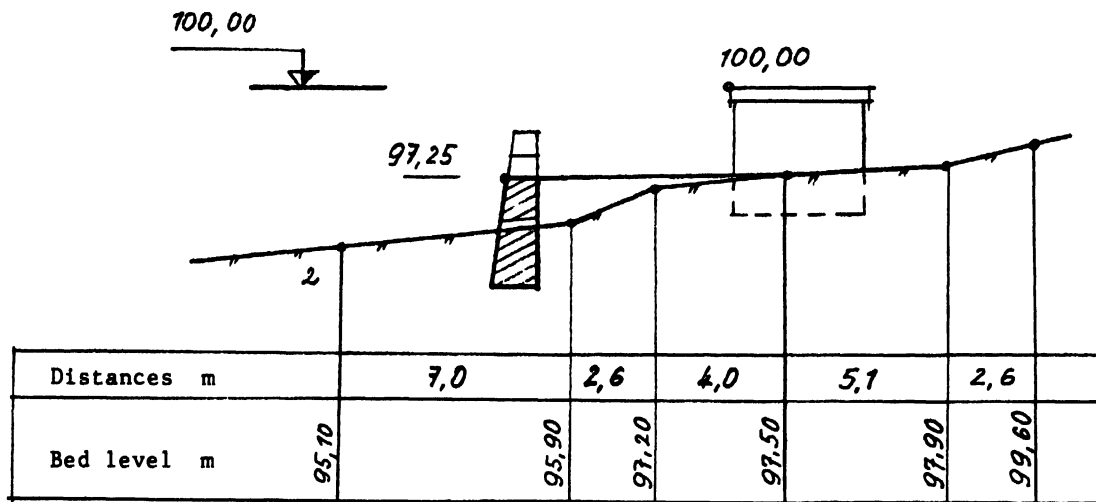
$$J = 2\% = 0.02$$



A series of check-dams made of roundwood at the top of a scree cone  
(Photo: M. Jedlitschka)

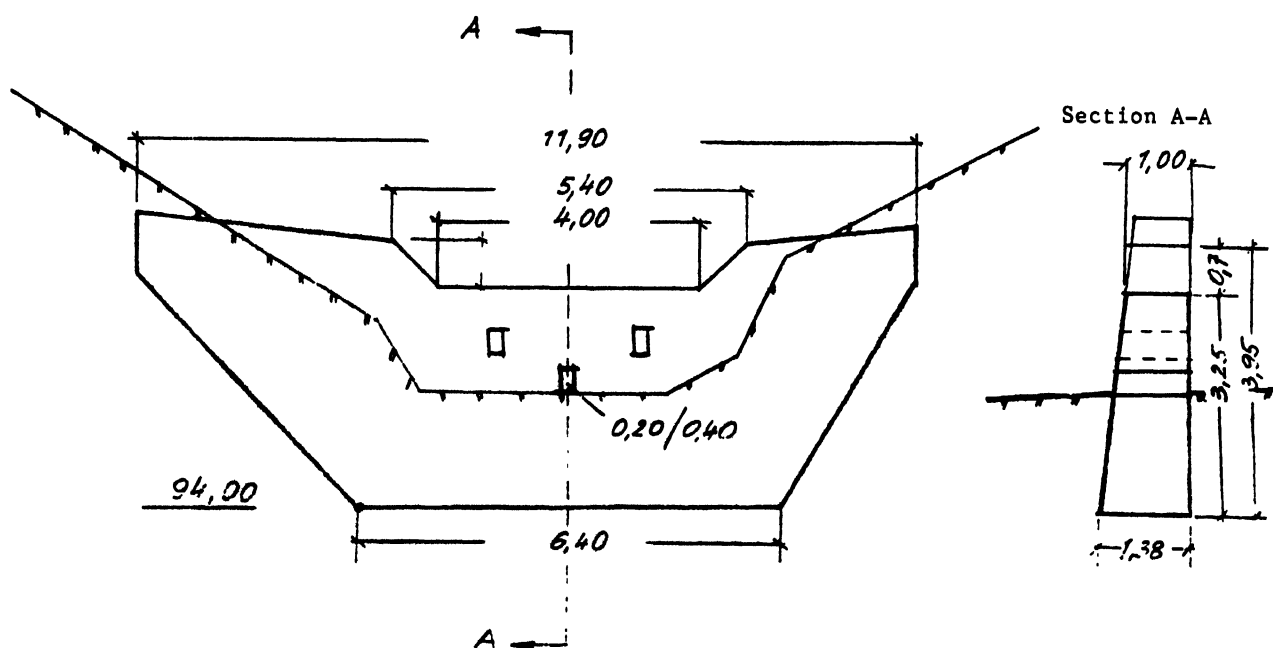
Fig. 4 CONCRETE CHECK-DAM

Longitudinal section



SCALE 1:200

Cross-section



SCALE 1:100

Estimated dimensions of the overflow section were tested as follows:

$$B_u = 4.0 \text{ m}$$

$$h = 0.7 \text{ m}$$

Abutment gradient 1:1

$$B_o = 5.4 \text{ m}$$

$$F = \frac{4.0 + 5.4}{2} \times 0.7 = 3.29 \text{ m}^2$$

$$U = 0.99 + 4.0 + 0.99 = 5.98 \text{ m}$$

$$R = F/U = 3.29/5.98 = 0.55$$

$$v = K \times R^{2/3} \times J^{1/2} = K \times 0.55^{0.66} \times 0.02^{0.5} = 40 \times 0.67 \times 0.14 = 3.75$$

$$Q_{\text{existing}} = 3.29 \times 3.75 = \underline{12.34 \text{ m}^3/\text{sec}}$$

More water than expected could be discharged through the overflow section ( $Q_{\text{existing}} > Q_{\text{required}}$ ).

2.2 Wing walls had a gradient of 10 percent and reached 1.3 m into the banks of the slopes.

2.3 Crest height

A height difference of 1.6 m between channel bed and crest followed from the longitudinal section.

2.4 Calculation of scouring depth

The following formula was used:

$$TK = \frac{4.75}{d_{ao}^{0.35}} \times H^{0.2} \times q^{0.57}$$

TK = height difference between water level downstream of the check-dam and bottom of the scour

$$TK = \frac{4.75}{5} \times 1.09 \times 1.80 = 1.86 \sim 1.85 \text{ m}$$

Overall height of the check-dam (T) therefore amounted to

$$T = H + TK + S = 1.6 + 1.85 + 0.5 = \sim 3.95 \text{ m}$$

2.5 Crest width (K) was determined at 1.0 m.

2.6 Calculation of foundation width (D)

The mean length of the check-dam's front view area was less than 8 m, so Kronfellner-Kraus's formula was applicable.

$$D = 0.35 (HK + h)$$

$$D = 0.35 (3.25 + 0.7) = \underline{\underline{1.38 \text{ m}}}$$

## 2.7 Determination of masses

The masses of planned works, i.e. in the present example the volumes of excavation pit and concrete check-dam, were calculated on the basis of detailed drawings. There are numerous methods for determining earth masses. The more accurate ones divide masses into simple geometric bodies, calculate their volumes according to standard formulae and determine the total volume by summing them up. If masses are stretched out and very irregular they are subdivided into cross-sections. The cross-section areas are then multiplied by the distances from one another.

A simplified method for calculating the volumes of trapezoidal bodies is to determine the front view area and multiply it by the diameter in the body's centre of gravity. This method can be applied in the present case to calculate the masses of excavation and check-dam.

Excavation. A cross-section of the excavation was drawn leaving sufficient space for the structure and substructure (about 0.5 m). The slope gradient in the foundation pit depends on the terrain solidity. The area between soil surface and foundation was multiplied by the diameter at the centre of gravity of the cross-section. The resulting volume was somewhat too big, so minor landslips occurring during excavation works were also accounted for.

The following figures were obtained:

area between soil surface and foundation (from drawing 1:100): about  $25 \text{ m}^2$ ;  
diameter at the centre of gravity: about 3.5 m  
volume of excavation:  $25 \text{ m}^2 \times 3.5 = 87.5 \text{ m}^3$  or approximately  $90 \text{ m}^3$ .

Concrete check-dam. The dam volume was determined by the simplified method. The front view area was about  $36 \text{ m}^2$ , the diameter about 1.20 m, the volume therefore amounted to about  $43 \text{ m}^3$  ( $36 \times 1.20 = 43.20$ ).

Back fill. After the concrete check-dam was finished the remaining foundation pit (channel bed as well as batters) was filled with excavated material. Downstream below the overflow section the material with biggest diameter was deposited to keep the scouring depth to a minimum. The backfill volume is in general equal to the difference between volume of excavation and volume of check-dam body between soil surface and foundation. For accurate calculations and big volumes the loosening-up factor of dug-out material must be considered.

The following results were obtained:

Volume of excavation: about  $90 \text{ m}^3$ ;  
Area between soil surface and foundation: about  $25 \text{ m}^2$  (see calculation of excavation);  
Diameter at centre of gravity: about 1.3 m;  
The volume of check-dam body between soil surface and foundation was assumed to be  $33 \text{ m}^3$  ( $25.0 \times 1.3 = 32.4$ ), therefore the back-fill volume amounted to about  $57 \text{ m}^3$  ( $90 \text{ m}^3$  minus  $33 \text{ m}^3$ ).



## 2.8 Cost calculations

On the basis of prices of similar construction works (see Appendix 2) and calculated masses, the costs of individual works and structures were determined. Cost of building site installations were added. In a case like the present they are very low - in fact, 5 percent of the total costs of individual construction works, if the check-dam is built during road construction. The total costs of individual construction works plus costs of building site installations are "net building costs". Additional costs are charged for overheads and risks, and private companies also add on for their profit. In the present case, about 10 percent was added to the net building costs for overheads and risks.

For the construction of this check-dam the following estimates were made:

<u>Work item</u>	<u>Mass</u>	<u>Price/Unit</u> (AS)	<u>Cost in AS<sup>1/</sup></u>
1. Excavation by machine	90 m <sup>3</sup>	55	4 950
2. Concrete B 225	43 m <sup>3</sup>	2 250	96 750
3. Back-fill by machine	57 m <sup>3</sup>	36	2 052
4. Building site installations			5 048
Net building costs			108 800
Overheads and risks (about 10 percent of net building costs)			11 200
Total costs			120 000 (US\$ 7 059)

The costs of a rock-filled log-crib check-dam are determined for comparison. The base width is determined by means of the following formula:

$$D = \frac{K}{2} + \sqrt{1.25 \times K^2 + \frac{T^2 \times W}{S}}$$

The following data are used:

K = 1.3 m (crest)

T = 4.6 m (total height of check-dam)

W = 1 t/m<sup>3</sup> (specific weight of water)

S = 1.8 t/m<sup>3</sup> (specific weight of filling material)

$$D = 0.65 + \sqrt{1.25 \times 1.3^2 + \frac{4.6^2 \times 1.0}{1.8}} = 3.07$$

<sup>1/</sup> AS = Austrian Schilling 1 US\$ = 17 AS.

The base width therefore amounts to about 3.1 m.

The simplified method is again applied for the volume calculation:

Front view area about  $36 \text{ m}^2$

Diameter at centre of gravity about 2.4 m

Volume of check-dam about  $86 \text{ m}^3$  ( $36 \times 2.4 = 86.4 \text{ m}^3$ ).

Cost of check-dam only (if price per  $\text{m}^3$  rock-filled log-crib structure amounts to 1 900 AS, see Appendix 2) is 163 400 AS as compared with concrete check-dam only: 96 750 AS. Under given conditions it is therefore more economic to build the concrete check-dam.



Concrete sediment check-dam

(Photo: M. Jedlitschka)

Appendix 1

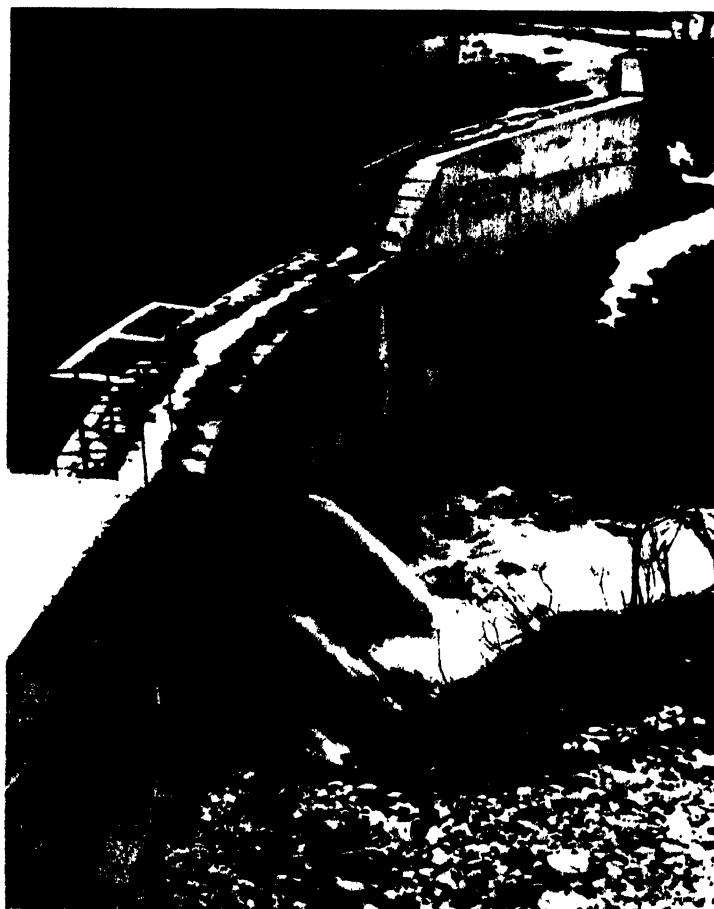
SIMPLIFIED DESCRIPTION OF WORKS AND EXPENSES IN TORRENT CONTROL

1. Excavation by hand 1 m <sup>3</sup>	4 unskilled worker hours including supervision 3 percent for tools
2. Excavation by machine 1 m <sup>3</sup>	0.08 excavator hours 0.03 hours for supervision
3. Material back-fill by hand 1 m <sup>3</sup>	2.5 unskilled worker hours including supervision 2 percent for tools
4. Material back-fill by machine 1 m <sup>3</sup>	0.05 excavator hours 0.02 hours for supervision
5. Concrete B 225 1 m <sup>3</sup>	6 skilled worker hours 0.3 tons portland cement 1.2 m <sup>3</sup> concrete gravel 0.1 m <sup>3</sup> saw-timber 10 percent for machinery
6. Rock-filled log-crib structures 1 m <sup>3</sup>	6 skilled worker hours 0.7 m <sup>3</sup> quarry stone 0.3 m <sup>3</sup> roundwood 5 percent for nails and tools
7. Gabion structures 1 m <sup>3</sup>	6 skilled worker hours 4.5 m <sup>2</sup> wire mesh 1 m <sup>3</sup> quarry stone 5 percent for wire and tools

Appendix 2

PRICES

<u>Work items</u>	<u>units</u> <u>(m<sup>3</sup>)</u>	<u>Price in AS</u>
Excavation by hand	1	910
Excavation by machine	1	55
Material back-fill by hand	1	570
Material back-fill by machine	1	36
Concrete	1	2 250
Rock-filled log crib structure	1	1 900
Gabion structure	1	2 400



Example of a sediment flushing dam  
(Photo: M. Jedlischka)

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Sturdy rock-built check-dam in mountainous terrain in Austria

## DEVELOPMENT OF WOOD HARVESTING TECHNIQUES IN AUSTRIA

by

Josef Wenzl

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Work output, particularly in felling by hand, depends on the site conditions, the felling method, the type of timber, weather influences, the slope and accessibility, equipment, workers' skills and the sequence of operations. All activities using hand tools are dynamic types of work which place considerable strain on the forest worker and require a high input of energy.

In Austria, in the past, crosscut saws were used for felling. The cutting performance of these saws varied according to the tooth shape, saw length and the degree of maintenance. The crosscutting tooth was the simplest shape from which various others (plane tooth, lance tooth) have been developed for high-performance saws.

For thinning operations as well as for cutting firewood, bucksaws and one-man saws were employed. Various types of axes were used for clearing the stem, cutting the notch, delimbing, etc. and for splitting operations. Manual debarking was carried out by means of devices such as pruning chisels and fork-shaped irons. Various types of peavies proved to be extremely valuable tools for use in timber felling as well as in skidding, loading and transport.

In most cases, felled timber on slopes was skidded by means of gravity, whereas on flat terrain it was usually pulled by animals. Laying out a fishbone skidding pattern of skidding trails on slopes substantially helped to protect the existing stand from damage. Skidding aids such as timber slips were laid out over long distances and removed immediately after skidding was completed.

Another technological development was the building of wooden timber chutes of different designs, which were, over several years, used for timber transport.

In alpine regions, one of the most important ways of moving felled timber in winter was with a hand sledge. By means of these sledges, coniferous and broadleaved logs, 4 to 9 metres in length, were transported to the valley on prepared skid trails. Moving these sledges up the slope required a tremendous amount of energy. Another important way to move timber at that time was by drifting and floating it on water.

In addition to existing energy demands, the growing mechanization of timber harvesting in the last few decades (use of power-saws, cable cranes, articulated four-wheel-drive skidders, etc.) has led to new forms of stress which can be hazardous to the forest worker's health. A substantial increase in work exposure or work requiring a certain posture (static work) and a higher degree of mental activities (concentration and attention strain) are characteristic features of present-day forestry work. The influences of noise, vibration and machine exhaust fumes on the forest worker must be considered in planning the work site. Therefore, it is the task of ergonomics to develop work physiological profiles for different operations in mechanized timber harvesting in order to prevent harmful effects on the health of forest workers.

Note: this was the introductory talk accompanying a slide show.



The influences of noise, vibration and exhaust fumes from the use of machinery such as power-saws on the forest worker must be considered. An instructor shows the participants the approach using the dosimeter to measure noise levels of equipment

(Photo: T. Pasca)



## LOGGING TECHNIQUES IN AUSTRIA

by

Anton Trzesniowski

Forestry Training Centre, Ossiach

### 1. INTRODUCTION

Technical articles, lectures and discussions offer solid evidence that Austrian forest management has attained the highest degree of mechanization. In some cases, references are even made to an overmechanization. Although mechanization is highly advanced, it applies to only a limited number of forest enterprises, since the use of forest skidders, debarking machines, mobile tower cable devices, processors, etc. is restricted to large forest holdings and individual forest contractors.

In small forest properties, especially in those forests owned by mountain farmers, most of the heavy labour is still done by hand. In other operations the power-saw has accelerated cutting, delimbing and bucking operations considerably and thus has reduced the time input for heavy physical work. At the same time, however, this innovation has introduced noise, vibration and other stress factors into this type of work. Wedging trees and piling branches have always been among the most strenuous parts of the felling process. Despite the introduction of mechanization, these phases still have to be carried out, and maintaining a prescribed felling direction is an essential prerequisite for the efficient use of machines with minimum damage to the forest.

The same is true of logging, in which - despite the introduction of mechanization - different types of heavy manual work still lead to accidents and to harmful effects on the health of the forest worker.

To produce wood economically, it is first necessary to build forest roads. The construction of modern forest roads may be considered the first phase in the process of mechanization. In the Austrian Federal Forests Enterprise the goal is to build 25 m of roads per hectare in mountainous regions where mechanized skidding is feasible. In large, private forest enterprises, road densities are between 30 and 40 m/ha, whereas the density of roads in small forest holdings is 40 to 50 m/ha. In addition to forest roads for trucks, some 40 to 80 m/ha of skid trails are built. The density of the road network is directly dependent on the size of the forest holding and thus on whether or not mechanization can be carried out. As Austria's largest forest holder, the Austrian Federal Forests Enterprise can afford to use large machines and thus requires fewer, yet carefully laid out, forest roads. In small forest holdings the choice is usually limited to agricultural tractors, thus necessitating a denser road network.

The second phase of mechanization in Austria involved timber harvesting, which has experienced the greatest and most far-reaching changes. It was necessary to revise thoroughly the size of staff, planning and organization and to adapt all of these to the actual conditions. Though machines such as power-saws, tractors, cable systems, processors, etc. have been introduced into forestry work with considerable operational success, they have also created problems.

Modern silviculture may be considered the third area of mechanization. Now that road construction and timber harvesting have to a large extent become a matter of routine, considerable attention has been paid to timber production in the forest and to possible ways of rationalizing and mechanizing. Examples of this are the planting of a smaller number of plants per hectare; major reductions in the number of stems in young stands; selective thinning with special work methods and machines; and the use of chemicals applied by various kinds of devices.

## 2. ORGANIZATION OF FOREST WORK

In Austria, forest work is carried out in various organizational forms. Some of these are: work done on the enterprise's own account; work done by contractors; work carried out by buyers; work contracted to farmers on a piece-rate basis; and work by machinery and mutual-aid cooperatives.

Most forest enterprises with competent managements work on their own account. Most forest workers are employed by the forest enterprise throughout the year or on a predominantly fixed basis and the necessary machines belong to the enterprise. The highest degree of mechanization is found in this type of enterprise. Examples are the timber harvesting combine of the Austrian Federal Forests Enterprise or the fully mechanized timber harvesting operations using mobile tower cable devices, forest skidders and processors.

Recently, the number of contractors has increased and they carry out nearly all types of forest work. These include many different forms of organization, ranging from the so-called "one-man contractors" to enterprises headed by managers with a staff of 500 or more. Some contractors employ mainly women and are specialized in afforestation, the tending of young stands, and so on. Many contractors employ mostly "guest workers" and carry out only timber harvesting work. In mountainous regions there are some contractors who concentrate on cable operations or timber transport using helicopters.

Many forest enterprises are moving away from operational work and employ a growing number of contractors, thus reducing the amount of administrative work, taxes and risks for the enterprise.

Work performed by buyers is limited to timber harvesting and in most cases to small forest holdings. Sawmills, the paper industry and carpentry enterprises often have their own forest machinery and their own forest workers, enabling them to buy timber on the stump. In particular, the paper industry tries to purchase small wood and carries out its own thinning.

Farmers working on a piece-rate basis are usually mountain farmers with low incomes, who have to seek additional earnings. They generally have their own tractors with forest equipment, power-saws and sometimes horses. They are extremely hardworking, and the forestry industry is more than pleased to employ them.

Machinery and mutual-aid cooperatives are organizations of farmers which have until recently limited themselves to the agricultural sector. However, they are now extending their activities to forestry as well. In these organizations farmers help each other with their machines, and the work is distributed from the centre of the organization by a manager. Various machines are purchased jointly and used in the machinery cooperative. This makes it possible, even for farmers with small forests, to work with expensive, high-performance machines. In general, ancillary equipment for agricultural tractors is purchased to make more extensive use of their capacity.

Since Central European forests are for the most part managed by a large number of forest enterprises, smaller cable devices are used more frequently than bigger ones. In Austria, the forest land is distributed as follows:

Agriculture and Forestry Census 1970

	Enterprises		Forest land	
	number	percent	number	percent
up to 5 ha	175 335	70.2	306 148	9.6
5 to 20 ha	57 819	23.1	548 118	17.2
20 to 100 ha	13 875	5.6	517 371	16.2
100 to 200 ha	1 377	0.6	188 888	5.9
200 to 500 ha	768	0.3	240 899	7.5
500 ha and more	<u>595</u>	<u>0.2</u>	<u>1 391 260</u>	<u>43.6</u>
TOTAL	249 769	100.0	3 192 684	100.0

The following harvesting methods are employed in the mountainous areas of Central Europe:

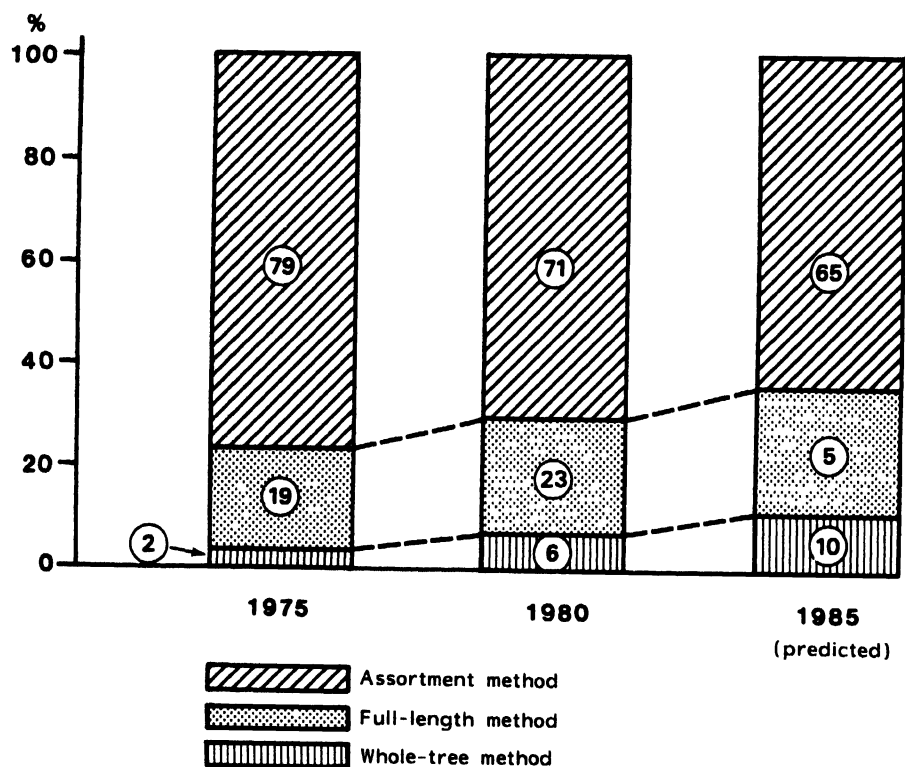
assortment method  
full-length method  
whole-tree method

Predictions as shown in the following bar chart indicate that the assortment method will continue to be dominant in the future, since it is better suited to the conditions of the small forest holdings prevalent in the region. It would be worth developing timber harvesting methods which require less hard work in smaller forest enterprises as well.

Partially mechanized timber harvesting refers to felling, delimbing and bucking operations by means of power-saws, i.e. using a combination of machine and manual work and skidding with the aid of machines (cable cranes or forest skidders).

Highly mechanized timber harvesting takes places when felling is carried out exclusively with power-saws and all other work, such as delimbing, crosscutting and piling of branches, is done with machines.

### HARVESTING METHODS

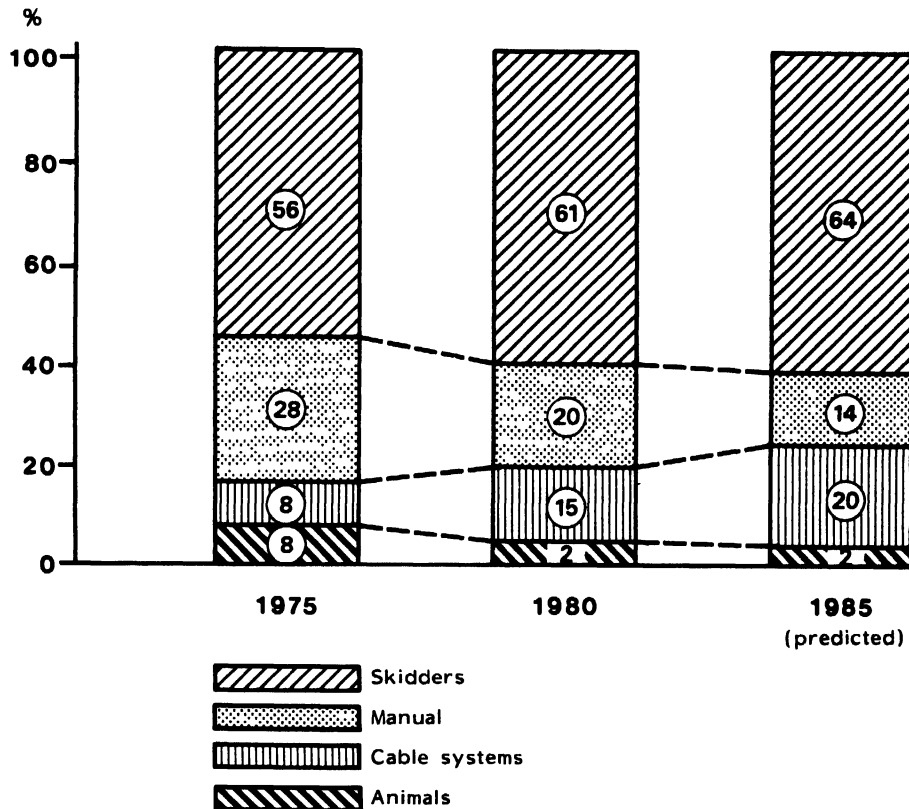


Source: Federal Forestry Research Institute, Vienna

Fully mechanized timber harvesting is harvesting where every phase - from felling all the way to haulage - is carried out by means of machines, such as feller-bunchers. These methods have not been introduced in mountainous regions because of the steepness of the terrain.

The following chart shows how the individual processes are applied in Austria:

### SKIDDING METHODS



#### Selective timber harvesting

In the harvesting of small timber the following methods are predominantly used:

- i) Assortment method - short: The trees are cut to assortments of up to approximately 4 m in length in the stands and transported, usually by hand, to the skidding corridor or the haul road;
- ii) Assortment method - long: The trees are delimbed and divided into assortments (such as poles and piling and saw logs) at the felling site. Extraction is carried out in part manually by using small cable winches or radio-controlled winches (interrupted transport) or by using skidders and cable yarders directly from the stand to the lorry waiting on the forest road (continuous transport);
- iii) Full-length method: Delimbing and trimming take place in the stand, whereas bucking and final limbing are carried out only after skidding. Skidding itself can be by either the interrupted or continuous transport method;
- iv) Whole-tree method: Felling and trimming in the stand. Skidding is to the skidding corridor or the forest road, where processors are used for mechanical conversion.

### Final cutting

In general the same methods are applied in final cutting as in thinning. In final cutting, however, larger, more productive machines can be used and the costs are lower.

Partial mechanization: Power-saws are used for felling, delimbing and crosscutting. For skidding, either the manual gravity method is applied or agricultural tractors, skidders, cable winches, cable cranes and, in rare cases, helicopters are employed.

High mechanization: This applies to the whole-tree method, which involves felling by means of power-saws, skidding of the whole tree using cable cranes or skidders, delimbing, crosscutting and sorting by means of processors. Work is carried out in an interrupted sequence of operations. In most cases, two to three men, each equipped with a power-saw, do the cutting. In terrain suitable for skidders, two or three forest skidders move the trees directly to the road. The processor is used after sufficient volume has accumulated to permit continuous operation. On steep slopes, felling is carried out first. Afterwards the timber is extracted using a mobile tower cable crane and moved by means of skidders to the roadside. Finally - after another delay - it undergoes conversion by a processor. Since every machine (power-saw, cable crane, processor) has a very different performance, it is possible in the interrupted sequence of operations to use the machines to almost full capacity.

## 3. MACHINES

Power-saws: These may be considered a highly advanced piece of machinery. Further improvements, with regard to noise, vibration, exhaust fumes, weight and operational safety, would be desirable.

### Classification of cable devices

The classification of cable devices as presented in this paper is based mainly on their practical application. This classification is also in line with FAO Forestry Paper 24: Cable Logging Systems, Rome, 1981.

#### Small cable winches

Power-saw - cable winches  
Radio-controlled cable winches

#### Machine-mounted winches

Fixed winches  
Bogies

#### Yarders

Cable lines  
Cable cranes (short-distance and long-distance)  
    gravity cable cranes  
    all-terrain cable cranes

### Mobile tower yarders

Small  
Medium  
Large

### Continuous mainline systems for thinnings

### Special constructions

In the following, individual cable devices are described in detail with particular regard to:

- specifications
- working method
- applicability
- performance and costs

### Small cable winches

Small cable winches are useful to collect low volumes of small-diameter timber and to improve the profitability of subsequent transport by means of bigger machines. Because of their low weight these devices can be employed almost anywhere.

### Power-saw cable winches

In Alpine regions various designs are used which are easy to operate, light and inexpensive. Examples are the Swiss SKG top-cable winch, the Austrian multi-KBF cable winch and the Akja winch.

### Specifications

These winches are mostly driven by power-saw engines.

Engine power:	4 to 5 kW
Weight of complete unit:	up to about 70 kg
Maximum pulling power:	8 to 10 kN (800 to 1 000 kp)
Cable speed:	0.6 to 0.8 m/s, about equal to walking speed
Drum capacity:	120 m x (6.7 to 7.5 mm)
General observation:	The winch is mounted on an individual gliding sledge - Akja - which makes it fully mobile.

### Working method

These small winches are anchored to trees and are used in two-man operations. The Akja winch can also be anchored, but its optimum employment is for a mobile one-man operation. The mainline end is fixed to a tree, and the winch pulls itself up along the cable.

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General observation:	The winch is mounted on an individual gliding sledge - Akja - which makes it fully mobile.

### Working method

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**Most frequent uses:**

- felling trees which are hung up
- upward logging of low-diameter timber
- extraction of timber from blow-downs or avalanches by separating entangled trees
- clearing a road trace by cabling the timber to the uphill side
- pulling out the mainline of forest skidders and cable cranes.

In addition, the Akja winch can be used in one-man operations:

- uphill and lateral transport of log-line
- material transport for cable crane supports
- uphill transport of poles and storage along the road
- lifting cable crane supports and tensioning of cables

**Applicability**

All small winches are designed as ancillary devices for bigger machines in thinning and logging operations of small-diameter timber. They are also useful in fires, floods and to recover vehicles. Not only is the low price a special advantage of these winches, but they are especially well suited for use in small-scale operations.

**Performance and costs**

If cones are used, 0.5 m<sup>3</sup> of timber can be transported in one load. Depending on the working conditions, two workers can log 10 to 15 m<sup>3</sup> of timber up to a distance of 100 m and one worker 6 to 12 m<sup>3</sup> of timber in an eight-hour day. One operating hour is calculated to cost AS 50 to 60 (US\$ 2.95 to 3.53).<sup>1/</sup>

**Radio-controlled cable winches**

These winches are not often used in alpine regions because they are usually rather heavy and expensive. Although they have many advantages in operation, forest owners hesitate to use them. The following radio-controlled cable winches have been used: Radiotir, Theissen, Nordfor, Waldrapp.

**Specifications**

Engine power:	4 to 12 kW
Weight of complete unit:	90 to 475 kg
Maximum pulling power:	8 to 30 kN
Cable speed:	0.6 to 1.5 m/s
Drum capacity:	150 m x 6.0 mm to 250 m x 6.0 mm
General observation:	radio control

<sup>1/</sup> AS = Austrian schilling. 1 US\$ = 17 AS.

### Working method

If the mainline is attached to a tree, the winch can pull itself to the worksite. A snatch-block pulley is used for lateral yarding of logs from all directions without having to change the winch's position. The working crew usually consists of one winch operator and one feller in the whole-tree method, and of two fellers in the full-length method or if the trees have many limbs. If the whole-tree method is used, the standing tree is attached, felled by the felling expert and winched by the winch operator using radio control. In the full-length method, the two fellers work independently of the winch operator. Radio-controlled cable winches can be employed for all the logging operations which were discussed under the section on power-saw winches.

### Applicability

Depending on the model, these winches can be employed for thinnings, pre-thinnings and small clear-cuts on all slopes, from flat to steep gradients.

Radiotir winches are no longer found on the Austrian market, having been replaced by other models. For terrain with flat to moderate slopes and small- to medium-diameter thinning timber, Theissen and Nordfor winches are the best suited. Waldrapp winches can also be used on steep slopes with large-diameter timber to be thinned. The remarkable innovation of these winches is radio communication, so that there is no annoyance to the winch operator from noise and exhaust fumes.

The radio-control system should have a smaller and handier design. For one-man operations the 'dead-man' release should be coupled with an acoustic alarm. In an emergency, the forest headquarters can thus be alerted immediately to a work accident. Use of the described winches in Austria showed that technical improvements are necessary without, however, complicating the design or making service and repair work more difficult.

### Performance and costs

Studies have shown that the Theissen, Nordfor and Waldrapp winches have roughly the same operating performance, i.e. 1.0 to 2.5 m<sup>3</sup> per hour related to the working time of eight hours per day. This performance figure applies to thinnings in Austrian mountainous forests with transport distances of 50 to 90 m, mean diameters of 8 to 14 cm and log lengths of 4 to 8 m. Cost for one operating hour (end of 1981) was calculated to be AS 100 to 120 (US\$ 5.88 to 7.06), whereas one forest worker costs about AS 180 (US\$ 10.59) per hour including all subsidiary costs and social contributions.

The Austrian Federal Forests Enterprise calculated costs of cutting, delimbing and skidding to the yarding strip to be AS 260 to 300 (US\$ 15.29 to 17.64) for broad-leaves and AS 360 to 400 (US\$ 21.17 to 23.53) per m<sup>3</sup> for coniferous timber.

### Machine-mounted winches

#### Skidders

In Austria, there are approximately 350 forest skidders and 340 000 agricultural tractors, about a quarter of which are fully equipped for forestry work. Approximately 60% of all skidding is with agricultural tractors and the rest with forest skidders. Half of the agricultural tractors are equipped with four-wheel drive. For use in forests, the minimum requirements for agricultural tractors are the following: protective tops, front shields with a branch deflector, skid-proof chains, four-wheel drive, lamp protection,

floor panels, power-assisted steering and a hydraulic system. Forest skidders are tractors with equal-sized front and rear wheels and four-wheel drive. Articulated skidders may also be considered forest skidders.

#### Skidding devices for tractors or skidders

Cable winches can be mounted directly on agricultural tractors on either the front or the rear, with the option of either one or two drum winches. Mounting of the winches directly is advisable only for tractors used exclusively or primarily for timber skidding. An additional tail blade is necessary to prevent the tractor's sliding. Cable winches are usually not advisable for use by farmers as it takes too long to mount them.

#### Skidding tongs

Skidding tongs with or without additional cable winches are mounted on the three-point hydraulic system and permit skidding in a one-man operation. For these devices, the terrain must be fully suited for operating a skidder. It is a pity that no advancements in the development of skidding tongs as add-on units for tractors have been achieved in recent years.

#### Skidding attachments

Skidding attachments are all ancillary equipment to be attached to the three-point hydraulic system. A distinction is made between skidding bogies, which have their own wheels (e.g. Holzkmacht bogie), and skidding winches with their own protective blades and mounting supports (e.g. Holzkmacht, Huber, Krasser, Farmi, Igland, Norse, Schlang and Reichert).

Whereas skidding bogies are built for heavy loads, skidding winches are suited for both heavy and light timber. The range depends on the cable length and thus varies between 80 and approximately 120 m. Some devices offer a limited remote control system with a control cable, whereas other machines are equipped with a radio-control system. Though all these devices can be operated only on the ground, they offer the advantage that the loads can be pulled from the stand to the tractor and loaded in one operation. In choosing a skidding attachment, the following criteria are decisive: low weight, easy and quick mounting, minimal space requirement, low vehicle load, dead-man's steering, strong cable winches, adequate mounting supports, protective blades, high performance and accident-safe design.

#### Yarders

In alpine countries a great variety of cable winches can be found. They are usually mounted on sledges, sometimes equipped with wheels or simply mounted on a simple frame. They have one or two winch drums (in rare cases three) with a drum capacity of up to 3 000 m. Special designs, which are mainly exported, have considerably bigger drum capacities of 5 000 m and more. Since these winches are extremely common and very frequently used, they are produced by a large number of manufacturers. The Austrian firms include Ganter, Hinteregger, Huber, Krasser, Koller and Nessler. The best-known Swiss models are Wyssen and Baco.

Yarders are usually combined with skylines for uphill and downhill transport. Although ground-lead winches are available for large-diameter timber, they are rarely used since this kind of timber can be logged with forest skidders.

### Cable lines

A discussion of the tradition of cable systems focuses automatically on the use of cable lines. In Central Europe cable lines are built or used wherever a modern forest road-net is not possible for various reasons, such as nature preservation, freshwater reservoirs, protective forests of all kinds, and the like.

As comprehensive literature on cable lines is already available, this paper will not discuss them any further.

### Cable cranes

Unlike cable lines, cable cranes are easy to transport, quick to set up and operable almost anywhere in the mountains. They are used for uphill and downhill transport of timber, they can lift or lower the load at any point of the trace, and have a further invaluable advantage: lateral yarding up to 50 m (at high wage levels up to 30 m) from both sides of the trace is technically feasible and economical.

Short-distance cable cranes are distinguished from medium- and long-distance cable cranes on the basis of the trace length.

#### Short-distance cable cranes

These are units which cover a distance of approximately 500 m. Planning, mounting and operation of cables and supports are easy. The time required for erection is less than 15 to 20 percent of the overall cable operating time. The most frequent method is the uphill transport of long logs of all diameters with "raised heads".

The most common short-distance cable cranes are equipped with skyline and open-end mainline, or with skyline, mainline and haulback line.

#### Long-distance cable cranes

These are used mainly for uphill transport for yarding distances of between 500 and 1 500 m. Gravity operation is possible at a distance of over 3 000 m and an altitude difference of 1 000 m. Careful planning and expert installation are important prerequisites for a smooth operation. With gravity operation, fuel consumption is low (approximately 1 litre per m<sup>3</sup> and 1 000 m of yarding distance), since only the empty carriage is pulled uphill and the loads are braked down to the valley station by an air wing brake.

Since the loads are to be carried above the ground, the skyline has to be mounted at a sufficient height. Setting-up times amount to 40 to 50 percent of the total cable operating time.

There are two groups of cable cranes:

- gravity cable cranes (with open-end mainline)
- all-terrain cable cranes (with endless mainline).

Gravity cable cranes are a Central European technological development. The cable winch has to be set up at the highest point of the cable trace. The winch, mounted on a sledge, pulls itself up to the mountain station along its mainline. For distances of 1 000 to 1 500 m, a crew of four men needs one working day for the uphill transport of the winch. If the terrain is very difficult, the winch is dismantled and pulled up to the mountain station by animals or a helicopter. The disadvantages of this system are that the operator has to walk to the winch every day; that spare parts must be carried to it; and that repair work may require a lot of time and money. For downhill transport, relatively weak winches are sufficient. The increasing number of forest roads means that more and more timber must be cabled up to the road, thus requiring the more powerful winch types. However, the operator does not need to walk to the winch every day.

All-terrain cable cranes are further technological developments of the gravity type and can be used everywhere and for any direction because of the endless mainline. The winch can be situated at any point of the system, preferably close to the forest road. Service and repair work are easier, and so is the work of the winch operator on the whole. Mounting times are somewhat longer, and installation is more complicated. This is why thorough planning and a well-trained crew are of paramount importance.

#### Working method with cable cranes

The cable crew consists of three to five men. In the best of cases, it suffices to have a winch operator who also detaches the load and a second worker for attaching it. The traditional crew consists of one winch operator, one man who attaches the load and one man who detaches the load at the road. Planning of a cable system has to be completed before felling, which in turn has to be completed before cable operation can start. Cabling always starts at the highest point of the cable trace. Because lateral yarding is always carried out along an upward diagonal, trees should be felled in such a way that they point toward the cable in a fishbone pattern.

#### Applicability of cable cranes

Gravity cable cranes may be used wherever the skyline can have a gradient of at least 20 percent. If the carriage and winch are equipped with all-terrain accessories, any terrain, even mud, opposite slopes, and normally inaccessible gulleys, can be reached.

#### Performance and costs

As a rule of thumb for the profitability of a cable crane working under the most difficult conditions, the timber produced in each trace must be equal to the length of the trace (e.g. if the trace is 500 m in length, 500 m<sup>3</sup> of timber must be cabled) since in most cases the terrain is more favourable, fewer supports are required and the cable device is profitable even if less timber is produced from the shorter trace. Short-distance systems are expected to yield 4 to 6 m<sup>3</sup> per working hour and cost AS 80 to 140 (US\$ 4.71 to 8.24) per m<sup>3</sup>. Long-distance cable cranes extract 2 to 5 m<sup>3</sup> per hour and the costs are in the order of AS 140 to 250 (US\$ 8.24 to 14.71) per m<sup>3</sup> of cabled timber, excluding the costs for felling and bucking.

#### Mobile tower yarders

Long setting-up times and increasing wages forced Central Europeans to rationalize. Under North American influence tower yarders were developed which are highly mobile, inexpensive to operate and the integral counterpart to the now well-developed road net. In Central Europe, a distinction is made among three sizes of yarders: small, medium and large mobile tower yarding.

The Central European machines are smaller than the American ones. They are always mounted on wheeled vehicles. The most essential building parts are the tower, the cable unit and the carrier vehicle including the engine.

### Specifications

The three sizes of mobile tower yarders differ according to the following details:

	Small	Medium	Large
mobile tower yarders			
<u>Tower</u>			
Height	up to 7 m	7 to 10 m	over 10 m
Guylines	2 (3)	3 to 6	more than 6
<u>Cable unit</u>			
Maximum load	600 to 1 200 kg	2 000 kg	2 000 to 4 000 kg
Number of winch drums	2 to 3	3 to 5	3 to 5
Skyline drum capacity	up to 350 m (13 mm)	up to 500 m (22 mm)	over 500 m (24 mm)
Maximum pulling power of skyline	up to 100 kN	100 to 200 kN	over 200 kN
of mainline	up to 15 kN	up to 60 kN	up to 150 kN
of haulback line	—	up to 40 kN	up to 100 kN
Maximum mainline speed	8.0 m/s	9.0 m/s	10.0 m/s
<u>Carrier vehicle &amp; engine</u>			
Engine power	up to 40 kW	up to 150 kW	150 to 200 kW
Weight of complete unit	up to 2 500 kg	6 000 to 10 000 kg	25 000 to 34 000 kg
Drive	engine of tractor	engine of carrier	engine of carrier
Vehicle	tractor or trailer	truck	truck
<u>Some models</u>	Koller K300 Hinteregger MINI-URUS  Andritz RM 2 000	Koller K500 Hinteregger URUS-STANDARD  URUS-middle class	Steyr KSK 16 Andritz HYDRO 80  Hinteregger URUS-Gigant  Koller K800
Required operating hours per year	600 - 800	800 - 1 200	over 1 000
Possible performance per hour	4 to 5 m <sup>3</sup>	6 to 15 m <sup>3</sup>	12 to 20 m <sup>3</sup>
Required annual performance	1 500 - 5 000 m <sup>3</sup>	5 000 - 12 000 m <sup>3</sup>	12 000 - 20 000 m <sup>3</sup>

### Working method

The smaller machines are most commonly used for the yarding of assortments, even though full-length and whole-tree loads may sometimes be yarded as well.

Felling, delimbing and crosscutting as well as pre-yarding into small loads of about 0.3 to 0.5 m<sup>3</sup> are carried out in a combination of machine and manual work. The cable corridors are laid out with a spacing of 15 to 30 m.

Medium-type machines are usually used for yarding assortments or full-length logs. For full-length logs, lateral yarding and storing of the load by means of a skidder is necessary. The space required along the road is at least three times the tree length. Moreover, immediate and continuous truck transport to the valley must be provided.

The large machines cable full-length logs or whole trees uphill or downhill. Further conversion is performed on the forest road, usually by means of processors. A forest skidder is employed for lateral yarding and storing of the timber. Continuous truck transport must be provided. Large mobile tower yarders have up to ten different cable sizes or types in one machine.

### Applicability

Small machines are used for thinnings, for low-quality final cuts, and in small forest units for the extraction of small amounts of salvage timber.

The assortment method is applied if the sap is running in the trees. Separate storage of more than two assortments is not economic.

Medium-sized and large tower yarders are used only for final cuts. The special applications of these machines are uphill and downhill transport of full-length logs or whole trees usually with "raised heads". A forest skidder for lateral yarding is needed. The winch site must be accessible by truck and all bridges must have sufficient carrying capacity.

Forest roads are frequently widened at the worksite to provide sufficient space for landing and storing logs (called a landing). Operating large yarders is economic only if 200 to 300 m<sup>3</sup> are produced for uphill transport and 300 to 400 m<sup>3</sup> for downhill.

### Performance and costs

Setting up small tower yarders requires a crew of two men working one to six hours depending on the number and position of supports.

Thirty to 60 assortments or 15 to 25 trees are yarded per operating hour. Costs for yarding and storing amount to AS 700 to 800 (US\$ 41.18 to 47.05) per operating hour. These costs include the skidder used for lateral yarding. For downhill transport the costs are 20 to 25 percent higher since another man is required to pull out the cable.

Medium- and large-sized machines require at least three men, who need one to two days to mount and dismantle a system for uphill operation and two to three days for a downhill system. Intermediate supports, which may be necessary, require a setting-up time of one to three hours each. Ten to 15 trees can be cabled per cable hour, depending on the distance, timber diameter, etc. The costs of one operating hour amount to AS 1 700 to 2 100 (US\$ 100 to 123.50) (including the costs of the skidder for lateral yarding).



Total costs, including cabling, pre-yarding and storing but excluding felling, all wages<sup>3</sup> and social contributions, amount to an average of AS 150 to 300 (US\$ 8.82 to 17.65) per m<sup>3</sup>.

#### Yarding trailers for continuous mainline systems

This group of cable units includes only the Steyr Timber-veyor. Manufacture of this Austrian technological development was started in 1975.

The maximum yarding distance is up to 400 m, and the width of the skidding strips is 1 m, with a 10-m spacing between strips. The machine, consisting of a truck with various cable winches and with an overall length of approximately 10 m, is located on the road exactly between two strips. One chain leads from one end of the machine into the first strip and a second chain from the other end of the machine into the second strip. At the end of the two strips the chains are led over two pulleys and linked so that the continuous system is closed. The chain is made up of pieces each of 17 m long so that it can be adjusted to any strip length. A choker may be attached to any chain link and can be fastened to individual trees. The crew consists of one operator and one man to load the cable. The operator detaches the load, collects several trees on a landing and transports the bunch laterally to the roadside, where it is detached automatically. The continuous chain is stopped only for attaching and detaching the load. The activities of the operator and of the worker are coordinated by means of a radio system. A diagram of the system is shown on the following pages.

The machine weighs 1 400 kg and has an engine power of 88 kW and a capacity of 400 m. The line speed is 1.4 m/s. The pulling power of the chain is 6 000 kp (59 kN), and the present model is used only for small-diameter trees.

#### Special constructions

Apart from the cable systems described above, there is a series of special constructions which were designed either by forest enterprises themselves or upon special orders.

One of the private owners uses a cable winch mounted on a truck. The truck also carries a collapsible tower so that it can not only transport the timber up to the road but also store it along the road.

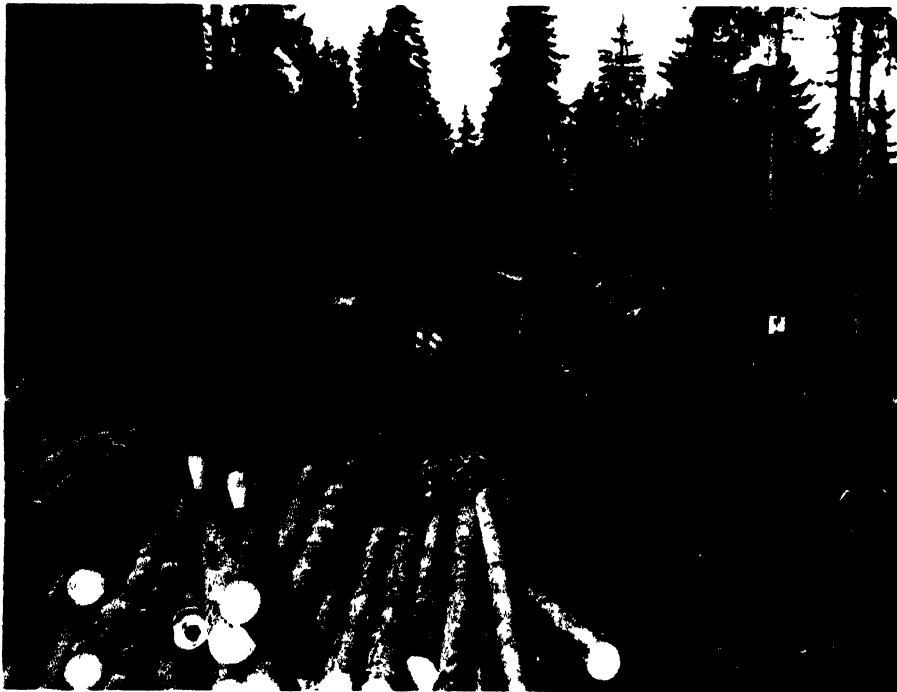
The Austrian Federal Forests Enterprise uses several prototypes of cable systems which are a combination of mobile tower yarders and mini-processors. Trees are transported uphill and immediately taken up by the processor to be delimbed, crosscut and stored on the road. One worker fells and attaches the trees, and the winch operator also operates the processor.

#### Processors to delimb, crosscut and sort

Scandinavian machines (Kockums, Osa) are available in Austria for large timber. Small timber processors have recently been developed in Austria which are particularly suited for mountainous areas. The processor head is mounted on a hydraulic loading crane and is thus extremely mobile. The Austrian Federal Forests Enterprise has developed the Processor 35, whereas Mayr-Melnhof, the largest Austrian private enterprise, has created the Processor MM 400.

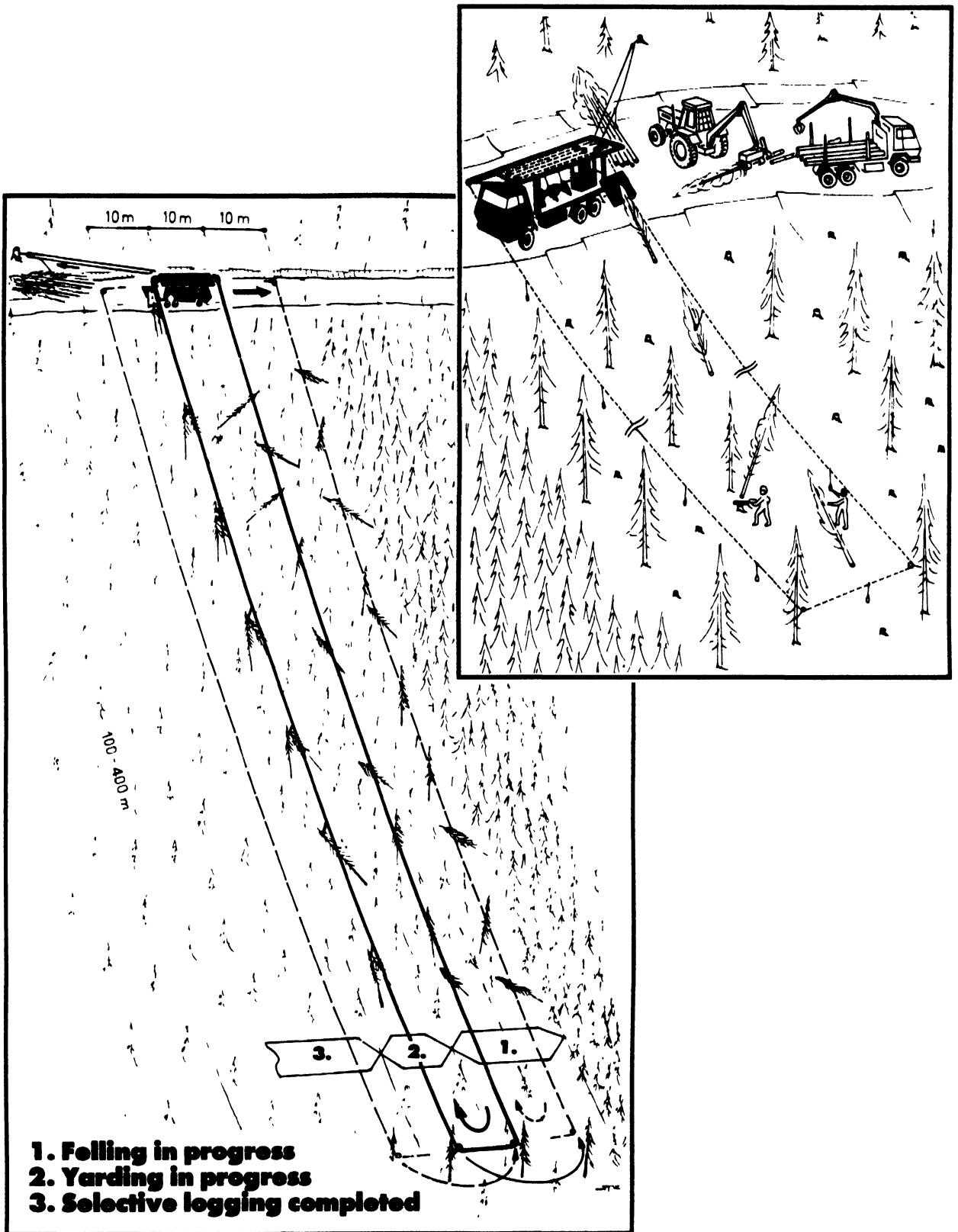
Mini-processors are now called crown processors and operate by using delimbing knives. In the case of the Processor 35 or Steyr mini-processors, these knives are designed as grapples. In the case of the MM 400, a separate hydraulic crane feeds the trees into the processor. A steel-tipped conveyor chain pulls the trees through the knife section, thus trimming the branches. The conveyor chain has built-in controls for an electronic length measurement, which is triggered by light beams. Five different lengths may be selected, enabling crosscutting to be carried out automatically by pushing a button. The maximum log diameter can be up to 40 cm. Depending on the system, cross-cutting is performed by means of hydraulic-powered circular saws or chainsaws. Mini-processors can be mounted on used forest skidders, tractors or lorries.

In general considerable attention is being paid in Austria to the limits of mechanization. In this connexion operating conditions and the structure of forest enterprises are the most important factors. Apart from the fact that every forest enterprise is different and has its own specific requirements, purchases for prestige reasons now hardly ever occur. To a large extent, the objectives set by individual enterprises are determined by detailed calculations on the one hand, and concern about maintaining employment on the other.

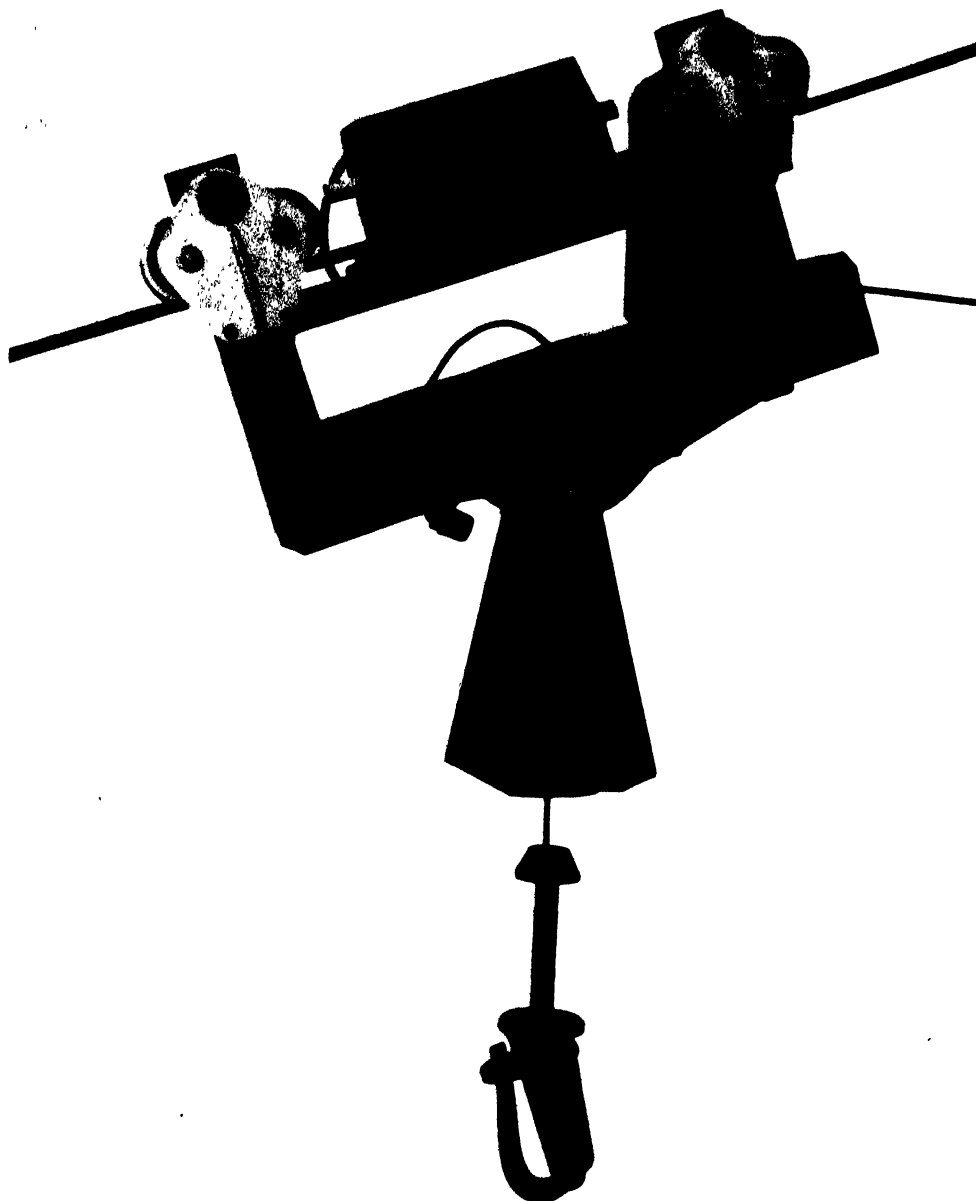


Processor picking up tree length logs for debranching, debarking, crosscutting and making assortments.

(Photo: O. Sedlak)



Continuous mainline system with a yarding trailer  
(from Steyr Forsttechnik)



A compact self-clamping multi-span carriage used in logging,  
construction or wherever material transport is necessary  
(Photo: A. Trzesniowski)

WORK ORGANIZATION AND WOOD HARVESTING METHODS OF THE  
AUSTRIAN FEDERAL FOREST ENTERPRISE

by

Winfried Egger  
General Directorate of the Federal Forestry Enterprise

1. LOCATION AND STOCKS

The Federal Forest Enterprise (FFE) which is the largest single owner of Austria's forest land, manages some 10 percent of the total area of the Republic of Austria.

A brief description of its ownership structure and organization will illustrate the functioning and management of the state forests.

Breakdown of state-owned forest holdings by area

	<u>ha</u>	<u>percent</u>
Commercial forest	371 437	44
Protective forest	120 519	14
Non-productive area	8 721	1
Total forest	500 677	59
Non-forest area: productive	37 294	5
: unproductive	303 884	36
Total non-forest	341 178	41
Total area	841 855	100

The FFE manages 15.7 percent of the country's total woodlands. The major portion of these forests (80 percent) is in the alpine region. Consequently, the FFE's share of forests in high-altitude locations markedly exceeds the nationwide average, and, as can be seen from the table below, state-owned forests account for a disproportionately low share in locations of up to 900 m above sea level. The altitude of state-owned commercial forests averages some 1 000 m, while on the average, privately-owned commercial forests are located at 850 m above sea level.

Table 1

ALTITUDE LOCATION OF AUSTRIAN FORESTS

Altitude above sea level	State-owned forest	Privately-owned forests
up to 300 m	0 %	3 %
300 - 600 m	14 %	25 %
600 - 900 m	24 %	27 %
900 -1200 m	32 %	24 %
1200 -1500 m	23 %	16 %
1500 -1800 m	7 %	5 %

With regard to slopes, state-owned commercial forests have, on the average, steeper gradients than privately-owned commercial woodlands. The table below shows the percentages of commercial forest areas for different slopes:

Table 2

SLOPES OF AUSTRIAN FORESTS

Inclination (slope)	State-owned (percent)	Privately owned (percent)
up to 10 percent	8	16
11 - 20 %	12	13
21 - 30 %	12	14
31 - 40 %	15	14
41 - 60 %	32	27
61 -100 %	21	16
more than 100%	0	0

The mean slope of state-owned commercial forests thus amounts to some 40 percent, compared with only 34 percent for privately-owned commercial forest holdings.

In state-owned forests, the ratio of coniferous species (predominantly pine) to broadleaved species (predominantly beech) is 76 : 24 percent, as against 81 : 19 percent in privately-owned forests.

The age of stands averages 70 years in state-owned commercial forests, 60 years in privately-owned commercial forests, and only 50 years in small holdings.

The growing stock of state-owned commercial forests averages 309 m<sup>3</sup> per hectare, while that of privately-owned commercial forests averages 257 m<sup>3</sup> per hectare.

## 2. ORGANIZATIONAL STRUCTURE

The organizational structure of the FFE is as follows: there is a managing board consisting of three members, each with separate responsibility for forest engineering, legal and administrative matters and commercial affairs, and an executive board (Director-General's office) subdivided in the same way into offices. These offices are further subdivided into departments and sections, each having specific responsibilities and tasks. The "functional distribution plan", which is established by the managing board and approved by the Federal Minister of Agriculture and Forestry, gives a detailed description of the responsibilities assigned to each organizational unit of the enterprise.

In addition, there are seven divisions which report to the executive board. Some of these are located outside Vienna to ensure easier and more profitable operations, as the state-owned forests are spread over the entire country.

The following bodies, which operate throughout Austria, are subordinated to the executive board:

- 76 forest administration offices
- 1 silvicultural centre
- 5 construction and machinery yards
- 1 technological centre
- 5 large sawmills.

Of the 76 forest administration offices, one is in Vienna, one in Burgenland, three in Carinthia, 13 in Lower Austria, 16 in Upper Austria, 21 in Salzburg, nine in Styria and 12 in Tyrol. Following the guidelines issued by the executive board, these offices are entrusted with the management of the forests in their districts. The administrative districts are further subdivided into 360 so-called "forester's districts".

The silvicultural centre of the FFE at Wieselburg serves mainly to provide cheap and efficient production of the seedlings and seeds required by the enterprise.

The construction and machinery yards are at Wien-Huetteldorf; at Steinkogl near Ebensee, in Upper Austria, some 20 km from the Ort Training Centre; at St. Johann in the Pongau/Salzburg; at Gusswerk in Styria; and at Kramsach in Tyrol. These yards have all the machinery, equipment and vehicles necessary for the construction and maintenance of forest roads as well as for mechanized timber harvesting. The build-up of construction and machinery yards, intended as an organization operating parallel to the forest administration offices, was started in the mid-nineteen sixties. Subordinated to the forest divisions, these yards function as auxiliary units in support of the district administration offices. They operate in accordance with the principle of full cost coverage and offer the district administration offices their services at unit prices (per cubic metre in wood harvesting, per metre in road construction, and per unit in bridge construction). This system has proved satisfactory, especially as regards the use and maintenance of machines and vehicles, the capacity of which could not be fully utilized by one forest administration office alone.

Construction and machinery yards have been instrumental in the development of machines and procedures within the enterprise.

Of the roughly two million cubic metres of timber produced annually by the enterprise, approximately 140 000 m<sup>3</sup> are sawn and marketed by its own sawmills. These are located at Amstetten/Lower Austria, Gusswerk/Styria, Neuberg/Styria, Tenneck/Salzburg and Kramsach/Tyrol.

### 3. HARVESTS

#### Volume harvested by the FFE in 1981

Type of cutting		Timber species	Annual volume in m <sup>3</sup> without bark	%
Final cutting	Commercial forests	Broadleaved	305 148	15
		Coniferous	1 035 643	51
		Sub-total	1 340 791	66
	Protective forests	Broadleaved	11 085	0
		Coniferous	55 827	3
		Sub-total	66 912	3
	Total volume	Final cut	1 407 703	69
Selective cutting	Commercial forests	Broadleaved	143 332	7
		Coniferous	481 583	24
	Total volume	Selective cut	624 915	31
	Total volume	All cuts	2 032 618	100

#### Distribution of 1981 harvest by federal provinces

Annual cutting volume, broken down by federal provinces and the share of state-owned forests (in m<sup>3</sup> without bark).

Federal province	Austrian Federal Forest Enterprise		Austrian total		Share of state-owned forests
	Volume	%	Volume	%	%
Burgenland	14 905	0.7	315 934	2.6	4.7
Carinthia	60 925	3.0	2 082 808	17.0	2.9
Lower Austria (including Vienna)	402 016	19.8	2 709 578	22.3	14.8
Upper Austria	522 830	25.8	1 933 640	15.9	27.0
Salzburg	572 903	28.2	1 115 930	9.2	51.3
Styria	252 401	12.4	2 961 275	24.3	8.5
Tyrol	204 017	10.0	861 468	7.1	23.7
Vorarlberg	2 621	0.1	207 902	1.7	1.2
Total	2 032 618	100.0	12 168 535	100.0	16.7



1981 volume, broken down into timber cut for the FFE's own account, sold on the stump, and timber harvested under easements (rounded up or down to 1 000 m<sup>3</sup> without bark).

<u>Disposal method</u>	<u>Volume</u>	<u>%</u>
Cut for own account	1 359	67
Sold on the stump	448	22
Easements	226	11
	<hr/>	<hr/>
Total	2 033	100
	<hr/>	<hr/>

(Note: 67 percent of the total volume cut by the FFE for its own account was produced by forest workers employed by the enterprise.)

1981 cutting volume, broken down into broadleaved and coniferous wood (in 1 000 m<sup>3</sup> without bark).

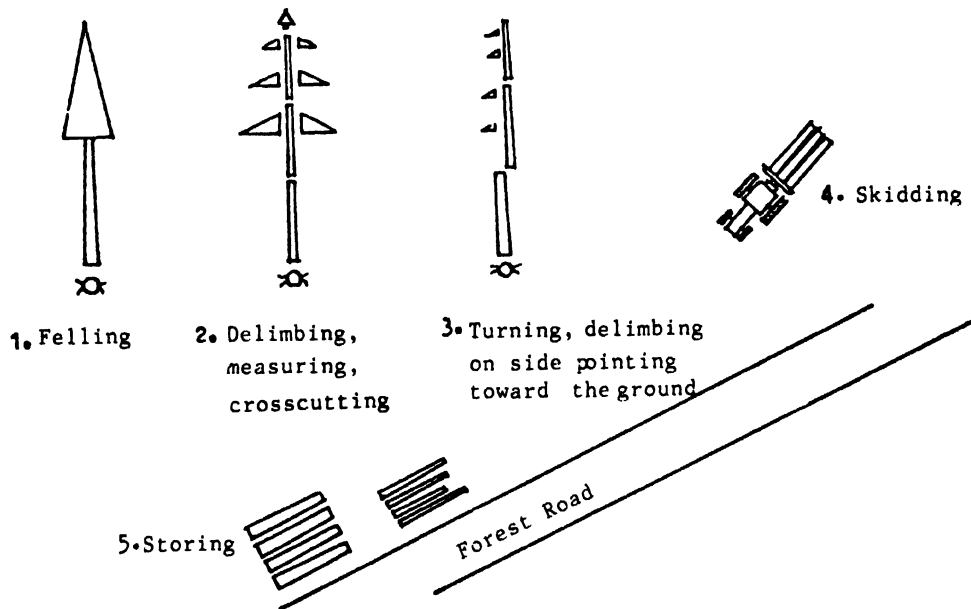
<u>Type</u>	<u>Volume</u>	<u>%</u>
Broadleaved	460	22.6
Coniferous	1 573	77.4
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Total	2 033	100.0
	<hr/>	<hr/>

#### 4. HARVESTING METHODS

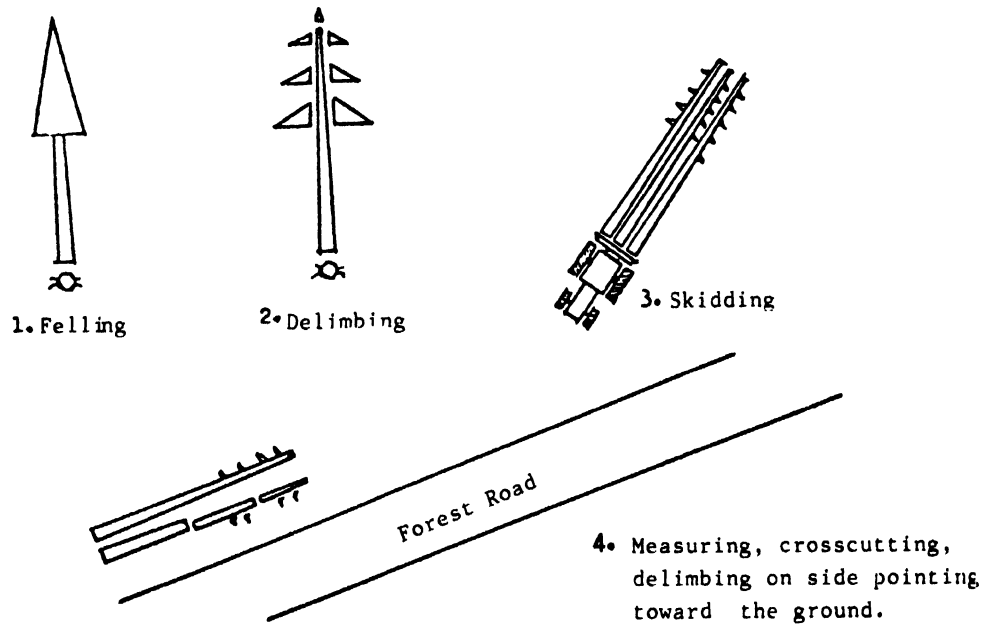
It has become common practice in forestry to name the harvesting method according to the form in which the timber is logged. Thus we distinguish between:

- the assortment method
- the full-length method
- the whole-tree method.

### ASSORTMENT METHOD



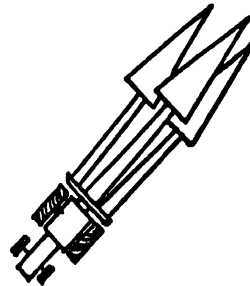
### FULL-LENGTH METHOD



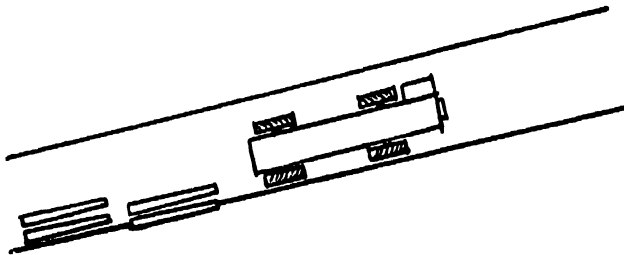
# WHOLE-TREE METHOD



1. Felling



Skidding



3. Either employment of mobile processor or transport to timberyard and final processing at the mill

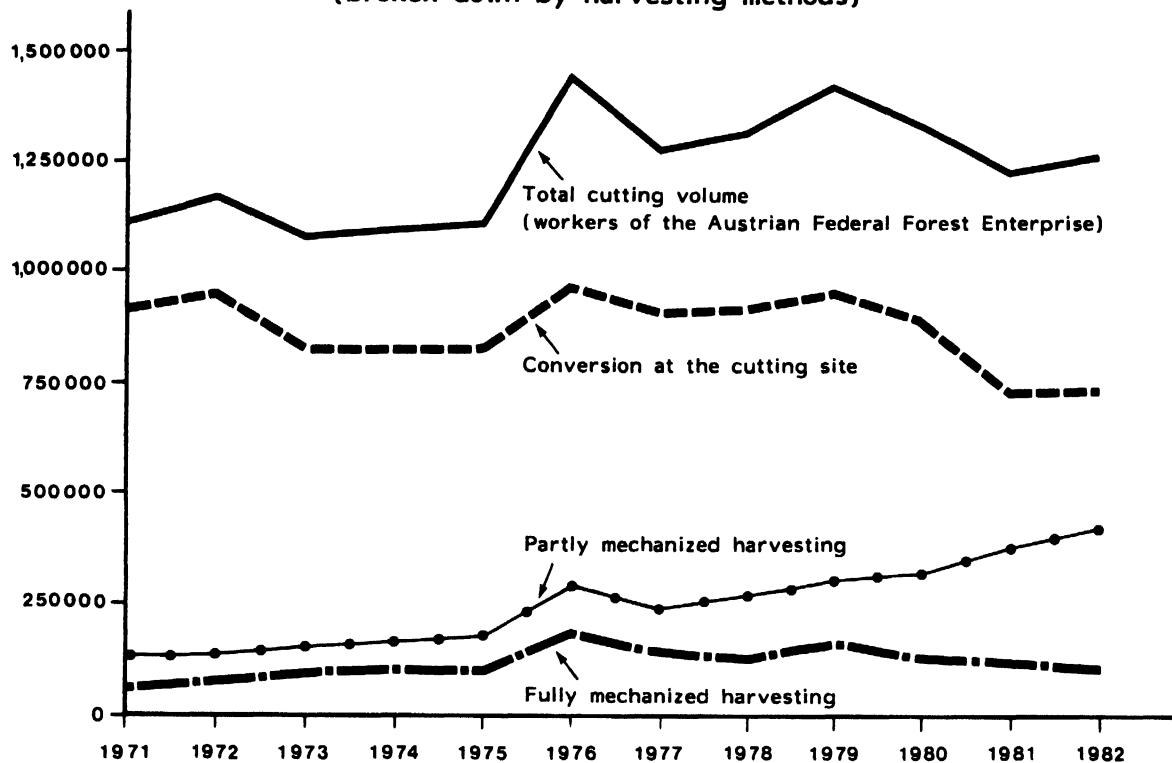
In the conventional assortment method, felling and delimbing are carried out with the aid of a power-saw, and the logs are then manually stored at the felling site. Conversion of the tree into assortments ready for sale also takes place at the felling site.

With the partly mechanized full-length method, felling, delimbing and topping are carried out with the aid of a power-saw, but the logs are crosscut only after transport to the forest road or the conversion site. Depending on the terrain conditions, logging is either with skidder or by cable.

In the highly mechanized whole-tree method only felling is done with a power-saw. Whole trees are transported to the forest road by skidders or cables and the trees are then processed mechanically on the forest road or at the conversion site.

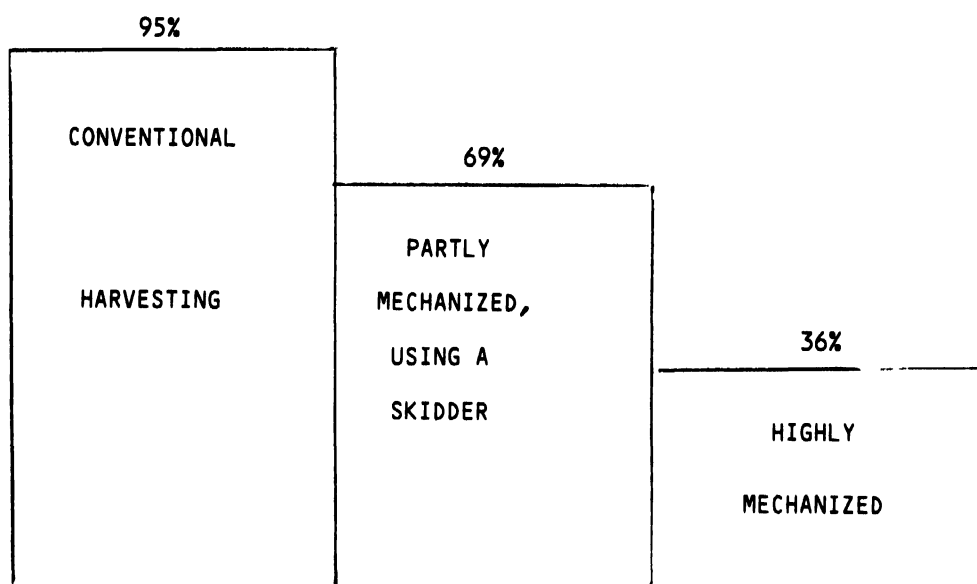
The timber volumes felled annually from 1971 - 1982 by FFE workers for its own account best reflect the development of timber harvesting methods used in state-owned forests. During this period the management made a conscious effort to increase mechanization and to reduce the proportion of logging by the conventional method - assortment logging. As a result, the proportion of assortment logging fell from 82 percent in 1971 to 58 percent in 1982.

**VOLUMES HARVESTED 1971 - 1982**  
(broken down by harvesting methods)



Varying wage intensities may serve as a guideline for assessing the effect of wage increases on harvesting costs. Over the past decades, wage costs have increased much more rapidly than machinery costs. Conventional logging by the assortment method is much more labour-intensive and consequently is much more sensitive to wage increases than either partly mechanized or highly mechanized methods.

5. WAGE INTENSITY OF THE THREE HARVESTING METHODS



For some years, operations have been focused on partly mechanized harvesting (full-length method), which will remain the most important procedure for years to come. This method, which accounted for 12 percent of total harvesting operations in 1971, has since been used more extensively (34 percent in 1982).

One of the reasons for the extensive use of this particular method is the large workforce of the FFE. In Austria, the only option open to a state-owned enterprise wishing to reduce the number of its employees is not to take on new workers upon the retirement or death of staff members. The partly-mechanized harvesting method offers the advantage that local forest workers may be hired and integrated into the mechanization process without major difficulties. Such workers will normally carry out the mechanical and manual jobs, such as felling and crosscutting trees, while the construction and machine yards with their special machinery are entrusted with conversion. This harvesting method offers a high degree of flexibility.

As a result of the present large workforce, the FFE cannot change over to fully mechanized harvesting as rapidly as would be economically desirable. Although the technology for full mechanization is constantly being further developed, it still accounts for a mere 6-8% of the harvest volume (with a peak of 13% in 1976 due to a disproportionately high incidence of wind-felled timber). This can be seen from a survey of the period 1971 - 1982.

To select the most profitable harvesting method for each forest enterprise, the following factors must be analysed:

## 6. COMPARISON OF WORK PRODUCTIVITY

PROCEDURE	At the felling site	Logging	On the forest road or at the storage site	PRODUCTIVITY per man-hour      per man-year		Workers required for production and transport of 100 000 m <sup>3</sup> annually <u>1/</u>
Highly mechanized	Felling and top-ping with power-saw	Whole-tree method	HEZ	2.09	3 344	30
			STRAMA	1.81	2 896	35
Partly mechanized	Felling Delimbing	Full-length	Secondary delimbing	1.00	1 000	63
Conventional harvesting	Power-saw No debarking	Assortment method, manual	Manual storage	0.48	774	129
	Power-saw and manual debarking			0.36	580	173

1/ Developed from the FFE's statistics on piecework

## 7. COST COMPARISON

A comparison of the costs for the three different harvesting methods used in final cuts, which was made by the FFE several years ago, showed the following:

Conventional harvesting, in which the assortments are produced manually with the aid of a power-saw, manually debarked and logged by means of an agricultural tractor owned by the forest administration office, has no future. Therefore, this method should be reduced as far as possible. The same applies to conventional harvesting with manual debarking. This method should be limited to salvage logging (isolated wind-felled areas, beetle-damaged trees) and to extremely small cutting volumes, where it can be applied profitably.

The cost of conventional harvesting is competitive with the partly mechanized method only when local logging enterprises (farmers) offer their services at very low prices. With small wood the farmer can offset less advanced technology more easily by a higher work input than is the case with large-diameter timber.

With larger mean diameters, this ratio shifts in favour of partly and fully mechanized harvesting.

Partly mechanized timber harvesting not only offers cost advantages, but is also preferable when the forest enterprise has a relatively large workforce, as it does not result in a surge of capacity. This method is less capital-intensive and requires a lower organizational input than highly mechanized harvesting; it may therefore be considered a transitional solution.

# COMPARISON OF COSTS

100%	82%	81%	70%	66%
Conventional harvesting with own personnel and own skidders, manual debarking	Conventional harvesting, own personnel, skidders from farmers, manual debarking	Partly mechanized, own personnel, skidders from farmers, manual debarking	Highly mechanized harvesting with own personnel, mobile processor, mechanical debarking	Partly mechanized harvesting with own personnel, field processor, timber left in bark adjusted for price reduction

Highly mechanized harvesting, including mechanical debarking and delimbing in the stands, is the cheapest method when debarking is required. In this country, however, demand for debarked timber is declining continuously, as sawmills throughout Austria are equipped with debarking machines and bark is increasingly valued as fuel.

Generally speaking, the assortment method is most appropriate when small volumes are to be cut per felling area (up to 150 m<sup>3</sup>) or when skidding distances are short (up to about 100 m). If there are no landings or if the terrain is extremely difficult, the assortment method is also advisable. It is preferable in thinning cuts or in selective harvesting because major damage to the remaining stand is avoided.

Large quantities of timber, long skidding distances and clear cutting as well as minor preparatory cuts are factors which justify the full-length method provided that adequate conversion sites and suitable skidding machinery are available.

As regards terrain, the full-length method using an articulated wheeled skidder with winch has proved satisfactory in areas with an average slope of 45 - 50 percent downhill and 25 percent uphill.

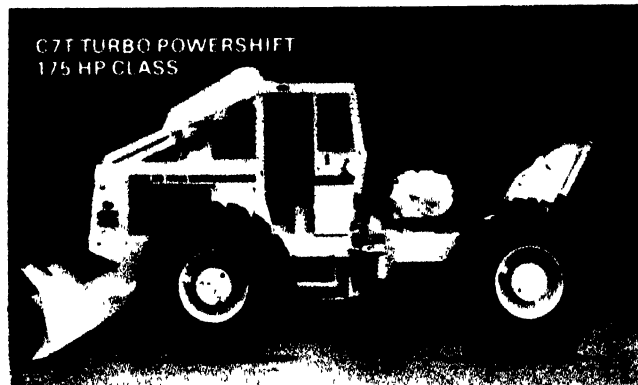
The whole-tree method requires a careful study of such factors as the volume of timber to be harvested and transport and skidding options. Cost accounting and calculations of per-caput productivity are a valuable source of information for decision-making.

In view of the heavy loads involved and the high friction caused by the branches left on the tree, more powerful skidders are required in whole-tree harvesting than is the case with the full-length method.

In selecting machines for the various harvesting methods, the planner must make sure that these will meet the requirements of the individual project with regard to the work, the workers, performance and cost.

## 8. MACHINERY

### MACHINE PLANNING



Performance-related  
Economy-related

Worker-related  
Work-related

A machine may be regarded as adequate for the work only if it has been designed for the particular type of terrain and work process, and damage to the remaining stand, to the forest floor, to the assortment produced, and to the road and landings, can be kept to a minimum.

A machine is adequate for the worker only if it meets ergonomic principles and requirements. Its design and safety features must be such as to guarantee easy, convenient and safe operation. These factors are prerequisites for the worker's sustained performance.

The machine must also be reliable. Before it is purchased, its specifications should be studied in relation to the work required of it. Profitability is, of course, a criterion of paramount importance. A machine can be used profitably only if its purchase price is reasonable or low in relation to its productivity; if it can be employed at capacity; and if its operating and repair costs are low. If it is used to 60 - 70 percent of its capacity, satisfactory results can be obtained.

A number of scientific institutes (Federal Forestry Testing Centre, Schönbrunn, for example) have worked out checklists containing all the above-mentioned criteria. Suitable and specially trained personnel are always needed to carry out economic and ergonomic studies and to select the right type of machine.

## 9. PLANNING THE WORK

It is the planner's task to make sure that adequately trained personnel are available in sufficient numbers. These people must receive further training on a continuous basis. Only the most qualified forestry personnel who receive continuous instruction and are under constant supervision are capable of fulfilling their tasks economically, safely, and with due regard to forest conservation.

With ever greater mechanization of wood harvesting, the training level of the personnel involved must also rise. Specific training should be offered for each harvesting method.



A machine will not do the work by itself.

It would be completely wrong to believe that planning consists merely of the acquisition of machinery and the intention to apply a certain work method. The more highly mechanized the harvesting method, the higher the planning and organizational input required.

Another decisive factor in choosing a particular work method is the wage system used. In planning work, adequate earnings under normal working conditions must be ensured for all well trained and experienced workers.

It is right to motivate workers, but too much incentive in the matter of wages can be dangerous, as it can threaten the life and health of the worker and lead to excessive wear on the machine as well as to damage to the remaining stand.

A fair wage system must combine a time-wage element and a performance-related wage element (piece-rate or premium wages).

The planner must choose the right wage system for the type of job to be performed. In Austria it has been found that a piece-rate system is very well suited to the assortment method, whereas for the other harvesting methods (whole-tree and full-length) in which machines are used, the premium system (basic wage plus performance-related premium) is normally applied.

Performance, work safety and the health of the forest are not determined by one single worker. Everyone involved in the work process contributes to the results.

Ensuring that this triple goal can be reached is the particular responsibility of the planner. He must be aware of his function and act accordingly.

In accordance with the principles described above, the FFE has for two years tried to raise its productivity through detailed work-planning in mechanized timber harvesting, and in this way to lower harvesting costs; to keep damage to the stand and to the forest floor to a minimum; to prevent accidents; and to humanize work.

In work-planning, particular attention must be given to the following:

- a) The market situation and the resulting sales prospects for timber are decisive factors in determining cutting targets.
- b) Just as important is the need to keep the workforce of the enterprise occupied, especially during the winter months. Therefore, work must be subdivided into summer and winter jobs. If possible, continuous employment should be planned.
- c) The harvesting method should be chosen with due regard for silvicultural objectives and forest protection.
- d) Annual cutting plans ought to be harmonized with ongoing and future opening-up concepts.
- e) The operations to be carried out in the course of the year should be coordinated with the capacity of auxiliary enterprises, such as construction and machinery yards.

- f) In order to minimize costs for personnel transport, operations and supervision, etc., single-stem extraction should be carried out on the basis of extraction zones.
- g) When cutting areas are selected, the time factor must be considered so that felling operations will not coincide with public leisure activities or seasonal needs of the wild life.
- h) Seasonal cutting should also be timed to coincide with demand for timber.
- i) Continuous transport should be ensured.
- j) Conversion should be tailored to market needs.

The purpose of work organization is to plan the best use of available labour, machinery and production techniques in accordance with the specific task assigned.

<u>Measures</u>	<u>Effects</u>
Detailed planning	- optimum use of machinery and equipment
Felling sequence	- safe and efficient work
Determining team size	- economic efficiency
Making worksites safe	- reduced stress
Organization of working hours	- satisfactory work and high performance
Arrangement of breaks	- satisfaction of employer and employee
Positive feedback	- better information flow

The purpose of detailed planning for opening up a site is to create working conditions which ensure an optimum use of labour and equipment while keeping damage to the stand to a minimum.

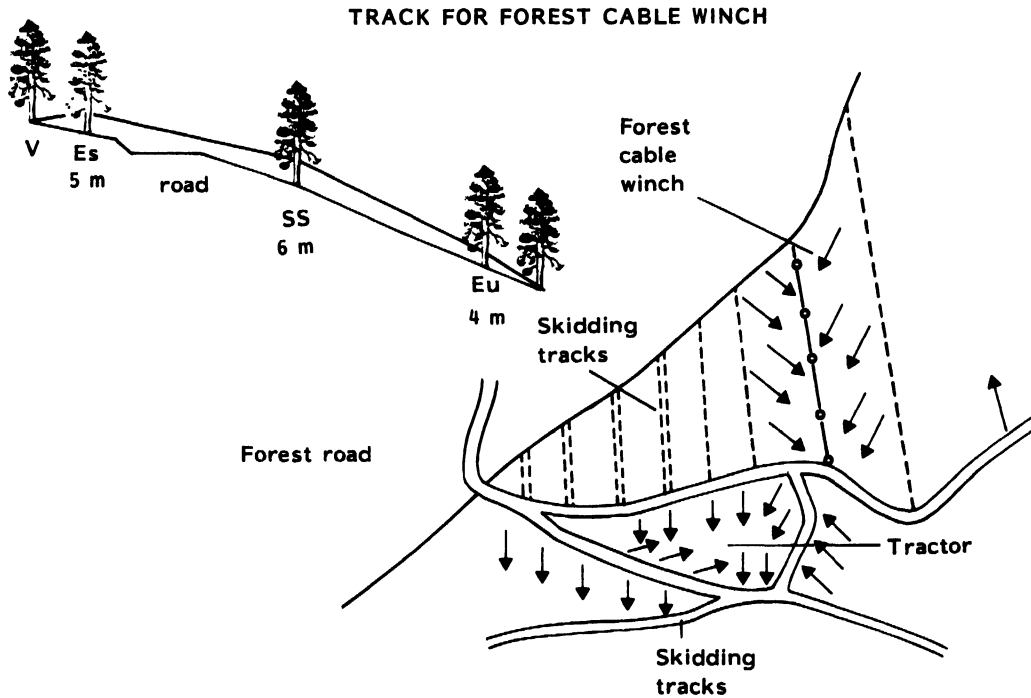
For the employee, detailed planning means organization and control of the work to be performed, which in turn results in safe working conditions, minimum physical stress, and efficient work.

Furthermore, detailed planning permits efficient use of the machinery and equipment provided for opening up the site. It also means that the operations will not entail unnecessary danger to man, machinery and equipment, and to the forest itself.

Factors in opening up a site which should be carefully planned are the following: skidding trails and tracks, skidding tracks from cable routes, and cable-crane corridors.

### 9.1 Planning the road net

Detailed development of the forest involves the laying out of skidding trails, skidding tracks, skidding tracks in combination with cableway tracks, cableway tracks, and cable routes.



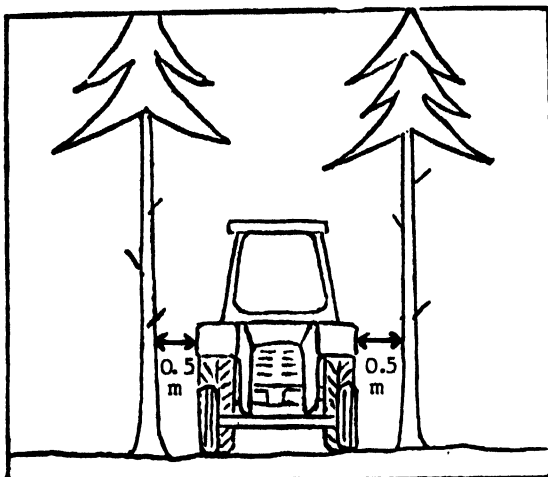
Skidding trails should be laid out with minimum expense. The routing and width of these rough trails depend on the skidding equipment used. Heavy equipment (high HP) can be used on quite steep trails although maximum gradients are usually dependent on the likelihood of erosion rather than on machine capacity.

Lightweight equipment requires relatively flat routing. Agricultural tractors are limited to no more than 25% gradient.

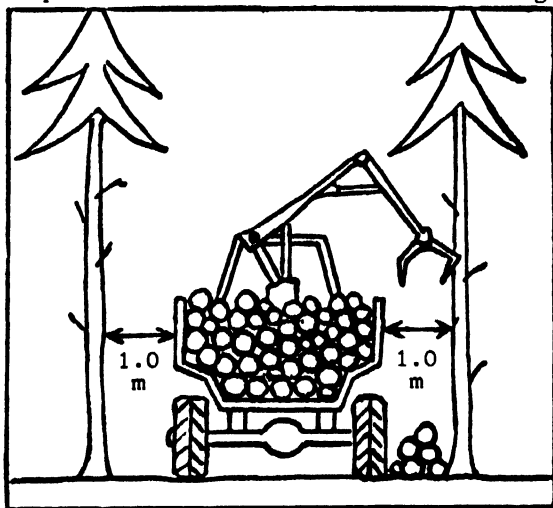
Skidding trails should have a minimum width of 2.5 to 3.0 m for accident prevention load safety and rapid transport. Skidding trails complement the forest road network and, together with skidding tracks, assist in opening slopes which are not too steep for forest vehicles. The distance between skidding trails varies from 100 to 200 m depending on the situation.

The wood is brought to the skidding trail either along the track or with the aid of a cableway (uphill) or manually with a peavey (downhill).

#### SKIDDING TRAILS IN COMBINATION WITH CABLEWAY TRACKS



Width of skidding track: width of vehicle + 1 m  
Cross-inclinations of the roadway should be avoided.  
If possible the tracks should run along the gradient.



Width of track for skidding with forwarder  
and crane loading: vehicle width + 2 m

The tracks should run as straight as possible and should as a rule be 2.5 to 3.0 m wide. That is, the width should be 1 m greater than the width of the vehicle. The roadway must be level and not slope to one side. If curves cannot be avoided, care should be taken to allow for the passage of the longest logs to be extracted. Skidding trails should join the forest road or the storage area at an acute angle. Plans must allow for room to turn the skidders around.

Skidding tracks should be placed as closely together as possible to facilitate extraction work. The ideal interval in young stands is 15 to 20 m. Spacing varies with the situation, however, and more favourable terrain takes precedence over a few metres one way or the other.

#### Skidding trails in combination with cableway tracks

In areas exposed to wind or for the late thinning of older stands, or where the forest terrain is unsuitable for vehicular traffic, the distance between skidding tracks varies according to situation and can, in some cases, be as much as 100 m. In areas in which this great distance is required between tracks, cableway tracks have to be set up.

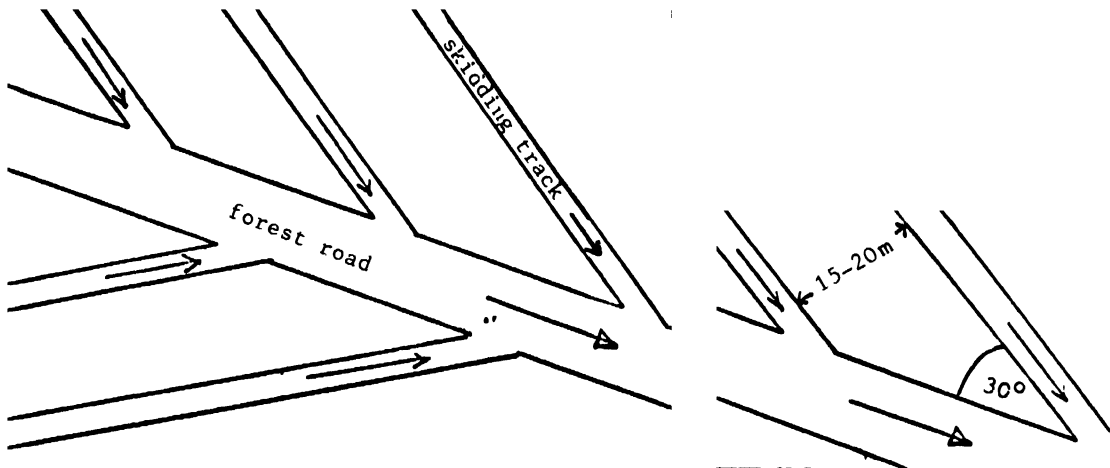
#### The skidding track

The skidding track is accessible to certain forestry vehicles. Usually individual trees have to be removed before a track can be used for traffic.

Skidding tracks must be routed in line with the terrain. Efforts should be made, however, to ensure that tracks are easily negotiable.

When it comes to a choice between stand protection or economy of operation stand protection takes priority. In some cases (swamps, large rock outcrops, etc.) track work is not profitable.

#### SKIDDING TRAILS IN COMBINATION WITH CABLEWAY TRACKS

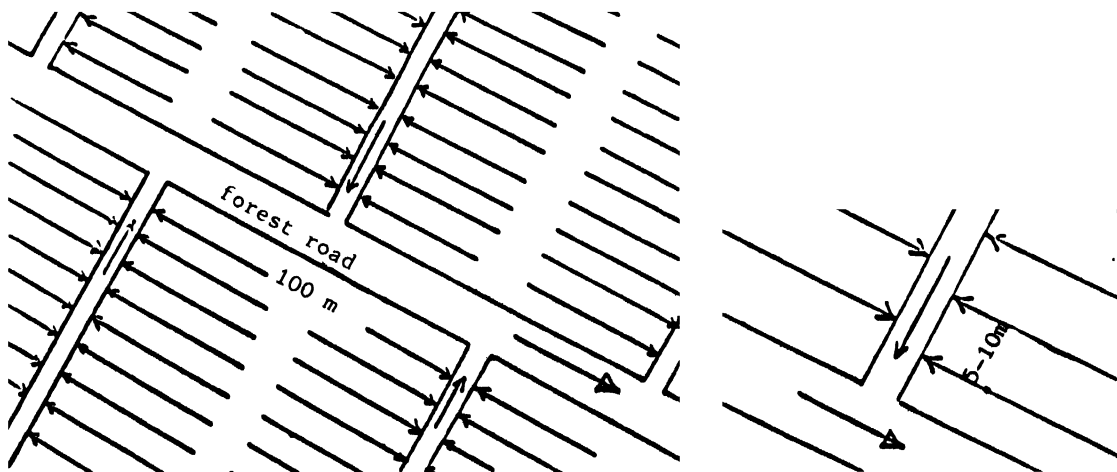


Distance between skidding tracks max. 100 m  
Width of skidding track max. 4 m  
Distance between cableway tracks 5 - 10 m  
Direction of cableway track - straight

The distance between cableway tracks in such cases is 5 to 10 m. The direction of the cableway track depends on the terrain, on the type of equipment used for the cable extraction work and on the workflow and the envisaged conversion method.

Generally speaking, in steep terrain the cableway track has to run right down the slope of the mountain and join the skidding trail or the forest road almost at a right angle. If the gradient is not too steep, it can be of great advantage to set up individual cableway tracks in a star-pattern leading to a central handling point. Depending on the length of the wood to be extracted and the subsequent handling, the cableway track can, in flat terrain, run either at a right angle to the skidding track (with conversion of extracted trees on the track) or for large assortments and entire trees, at an acute angle to the skidding track.

#### SKIDDING TRAILS IN TERRAIN ACCESSIBLE BY WHEELED SKIDDER



Skidding tracks join the skidding trails or forest roads at an angle of about 30°. Optimum distance between skidding trails 15 - 20 m.

### Cableway routes

The layout, length and distance between cableway routes depend on the terrain, the type of equipment and the work process. When the layout of cableway routes is planned, it is important to take into consideration the entire workflow involved in the harvest, and to make clearcut decisions based on the need to protect the stand and to work profitably.

### Detailed opening-up plan

1. Select area to be opened up and mark it on the map and in the field.
2. Decide the direction of timber extraction.
3. Fix extraction boundaries (starting and end points) provisionally.
4. Carry out repeated reconnaissance of the selected area; then work out the ideal opening-up plan with due regard for existing roads or trails.
5. Determine the opening-up system (skidding trails, tracks, cable routes and corridors).
6. Locate landings and handling sites.
7. Mark skidding trails and tracks, cableway routes, etc. and mark the trees to be felled or used.
8. Decide whether the butt ends or the tops of the logs should face the direction of extraction.

### Considerations for optimum skidding

1. Damage to the stand should be kept to a minimum.
2. Skidding should not cause subsequent erosion damage.
3. The workers should not be subjected to excessive stress or exposed to special dangers in skidding operations.
4. Skidding should be possible at any time of the year. The condition of the timber (in bark or branch stubs in contact with the ground) should not hamper skidding.
5. When the skidding system is selected, the log size is a determining factor.
6. Skidding costs should be kept as low as possible; however, these have to be considered in relation to total logging costs.

## 9.2 Felling sequence

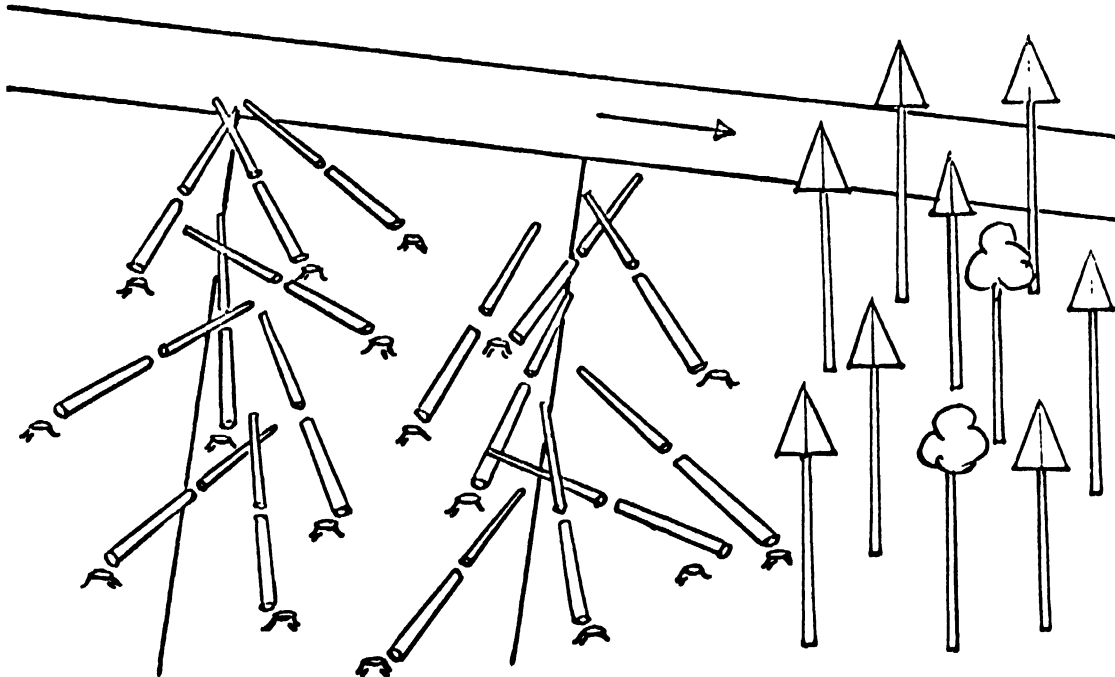
The felling sequence should be chosen with consideration for efficiency and human factors and for the least possible damage to the forest.

Early planning must include consideration of the direction of skidding, determination of the felling direction and determination of the sequence of operations (beginning and continuation of operations).

Furthermore, the felling sequence determines the time and place of wood harvesting operations (whether felling and skidding constitute one work cycle or whether all stump area operations are completed before skidding starts, and so on). The sequence of individual operations ranging from felling to crosscutting is certainly not always the same, and should be arranged in such a way as to ensure safety, efficiency and protection of the forest. When the felling sequence is determined, these factors should be taken into account. Some practical examples illustrate this:

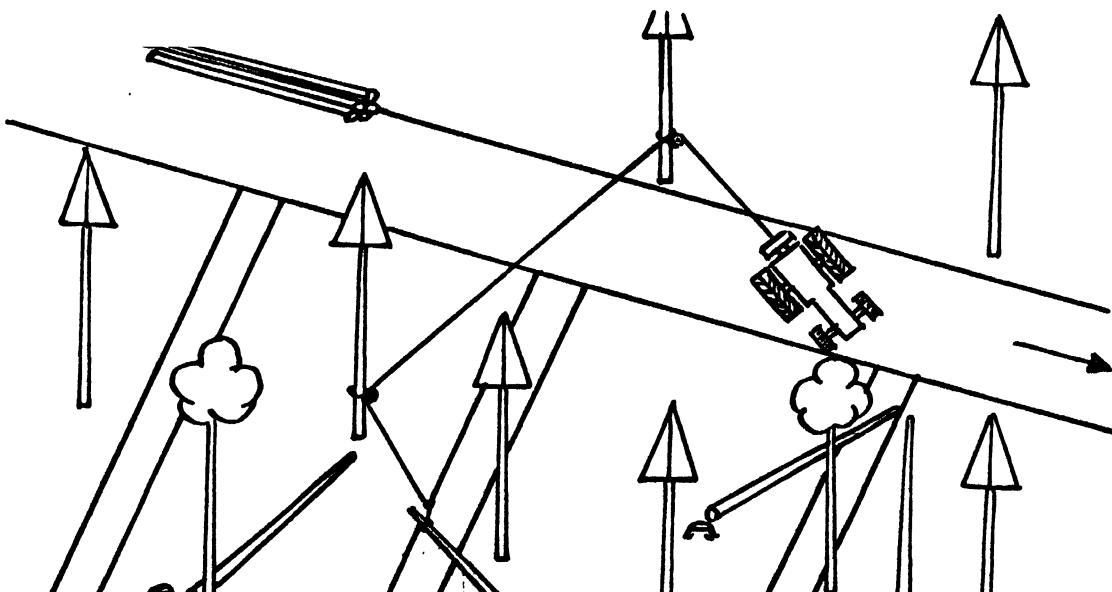
#### FELLING SEQUENCE FOR STRIP FELLING

Uphill skidding by cable for assortment method



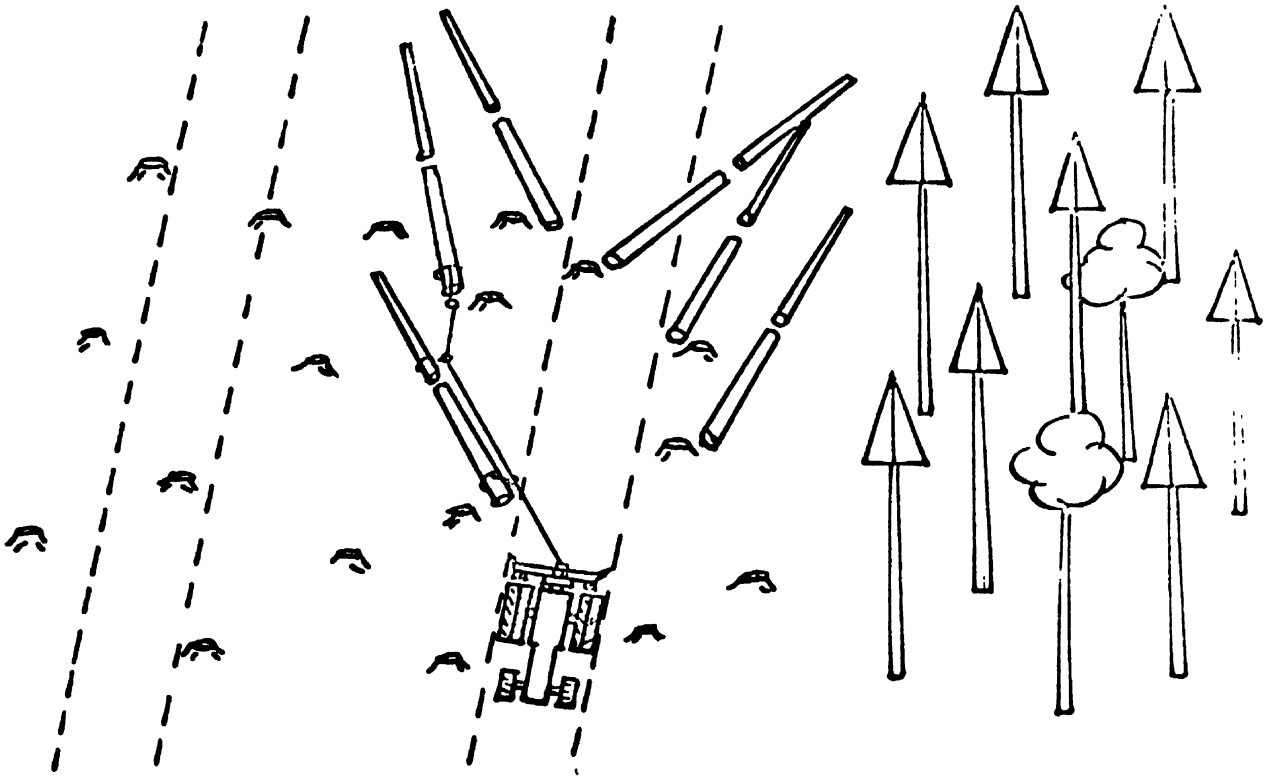
#### FELLING SEQUENCE FOR SINGLE-TREE FELLING

Uphill ground-skidding by cable for full-length method



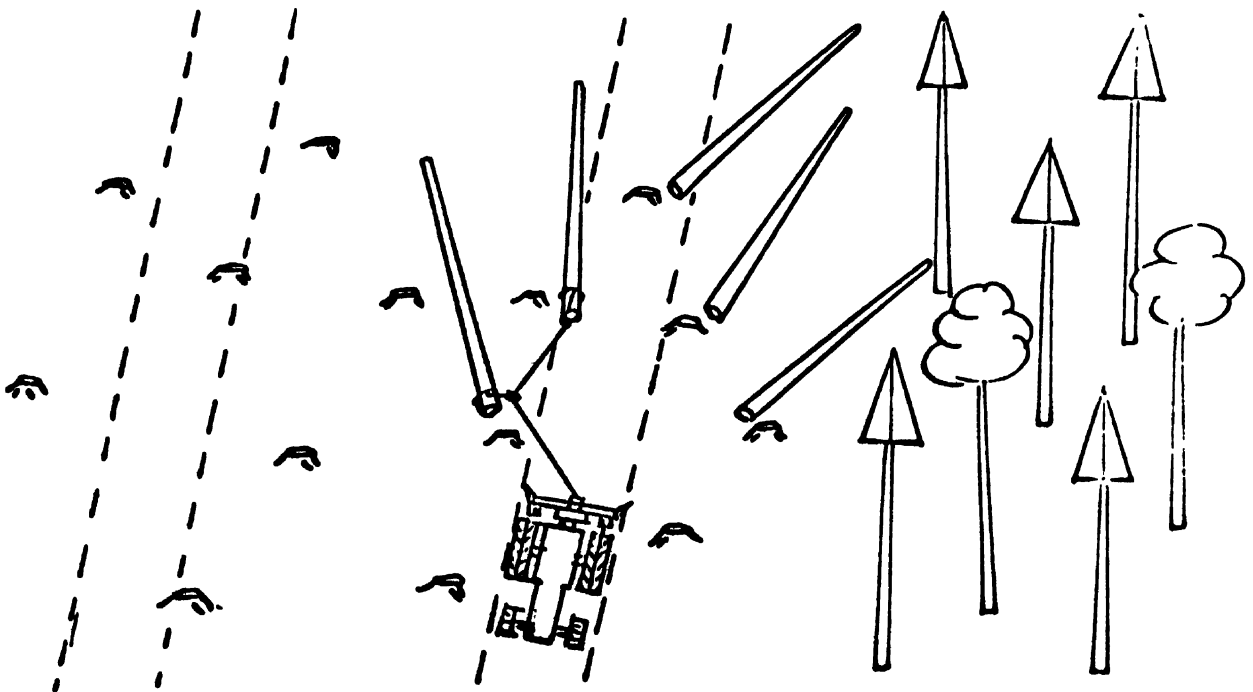
## FELLING SEQUENCE FOR STRIP FELLING

### Downhill operation by wheeled skidder for assortment method



## FELLING SEQUENCE FOR STRIP FELLING

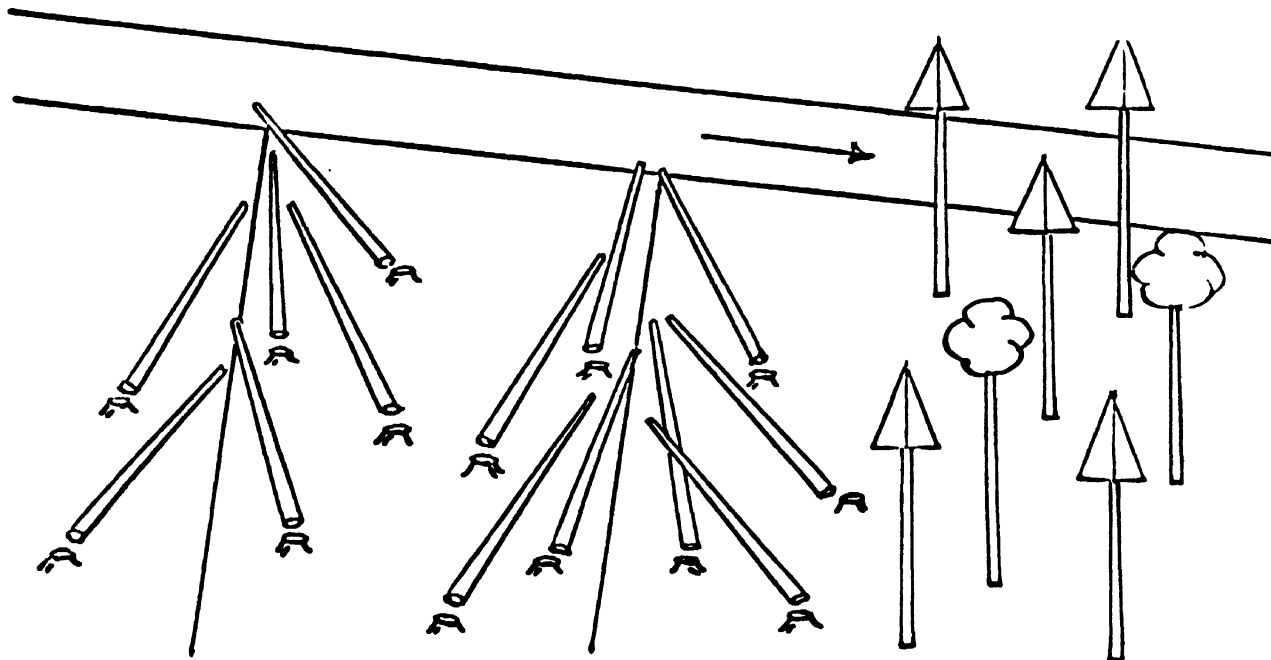
### Downhill operation by wheeled skidder for full-length method





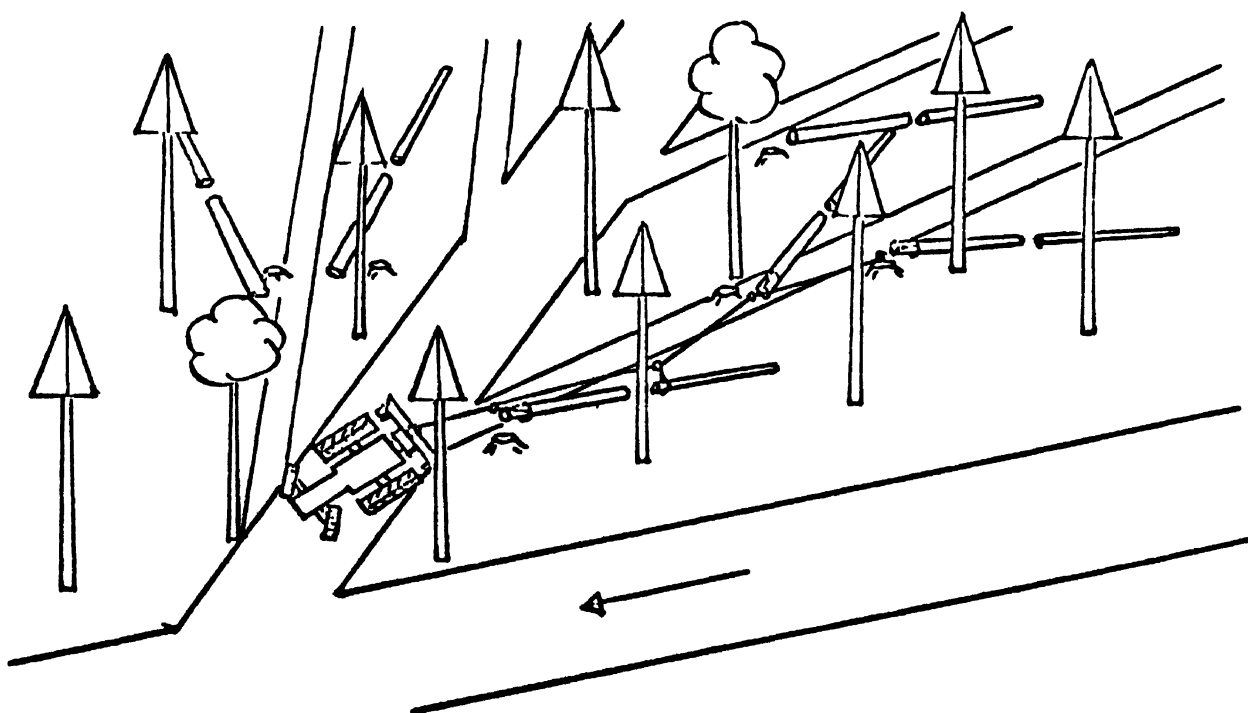
### FELLING SEQUENCE FOR STRIP FELLING

Uphill skidding by cable for full-length method



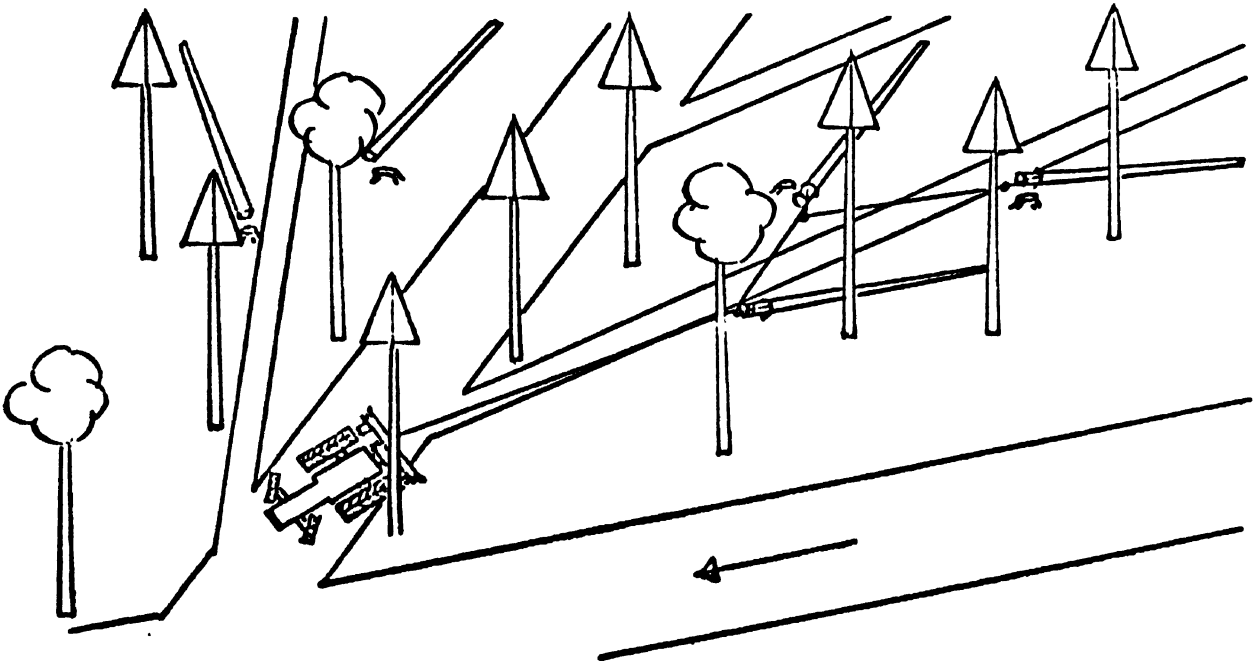
### FELLING SEQUENCE FOR SINGLE-TREE FELLING

Downhill operation for assortment method with skidder on skidding track (low slope gradient)



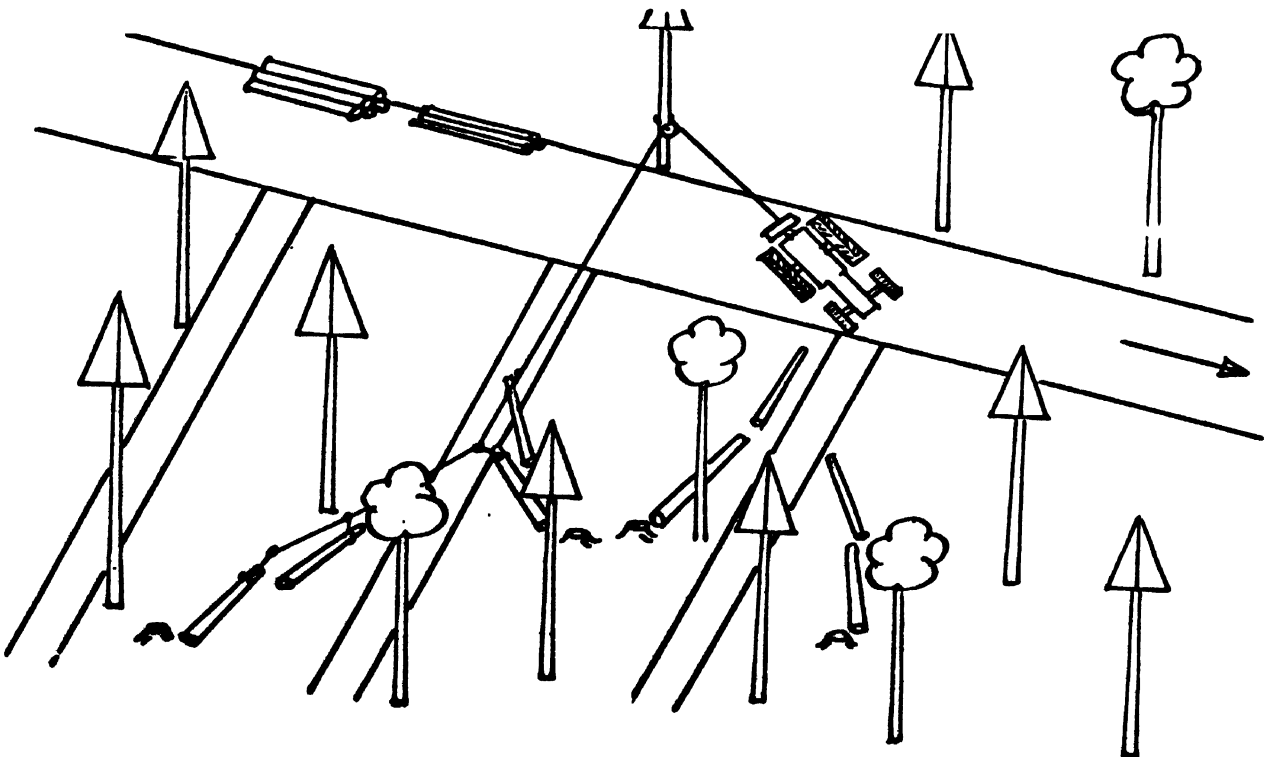
### FELLING SEQUENCE FOR SINGLE-TREE FELLING

Downhill operation for full-length method with skidder on skidding track (low slope gradient)



### FELLING SEQUENCE FOR SINGLE-TREE FELLING

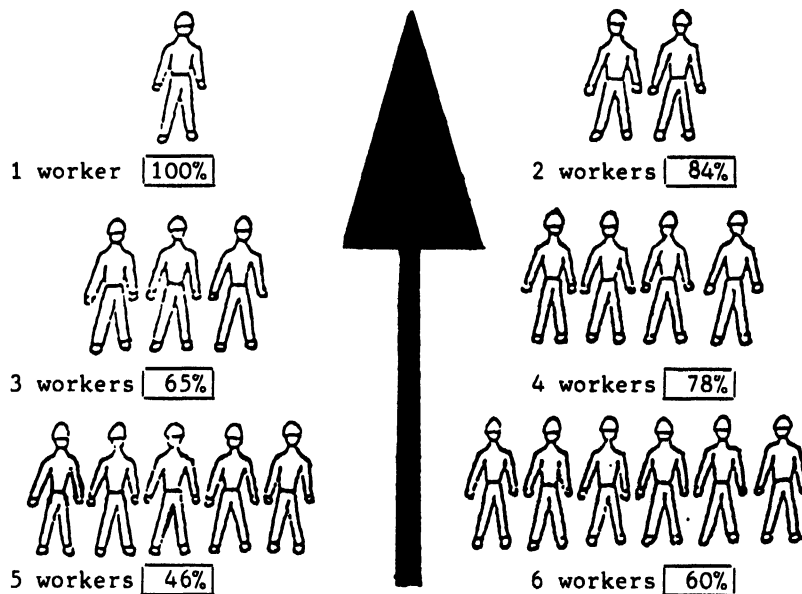
Uphill ground skidding by cable for assortment method



### 9.3 The work crew

In general, the selection of the correct size of the work crew is a key decision in the organization of work. The bigger the crew, the greater the danger of personality clashes and the greater the mutual exposure to danger. With work safety and increased performance in mind, work organizers should try to keep gang sizes small, and to assign tasks to one man only whenever this is feasible.

#### EFFICIENCY DEGREES OF HUMAN GROUP WORK



Reduced idle time, less stress for the individual worker, reasonable running periods of power-saws, more diversified and dynamic work, and increased safety are the obvious benefits of proper work organization.

One-man work means that the stump area operations are carried out by one man only while the others do the same work at a safe distance. The minimum permissible distance is one and a half tree-lengths, while the maximum distance is just within earshot. The sequence of operations on the tree is of special economic and ergonomic significance, which should not be ignored by work organizers. Moreover, the creation of a safe working place, the organization of working time and the arrangement of breaks that take into account the stress to which the worker is exposed contribute to both more safety of the individual worker and a higher performance level over long periods. Work can be done effectively only for a certain period. According to studies by Professor Lehmann the best average performance is achieved with a working time of five to seven hours including delay time and short breaks. If wood harvesting lasts eight hours a day the work results are still satisfactory; if the working time is more than this, the average performance shows a sharp drop due to increasing fatigue.

As a consequence, the precision of work deteriorates and flagging concentration results in a higher risk of accidents. It has been known for some time that the workload can be considerably reduced and accidents avoided if work is interrupted by short breaks.

Positive feedback, continuous training and the provision of suitable tools and equipment should be a permanent concern for those organizing work.

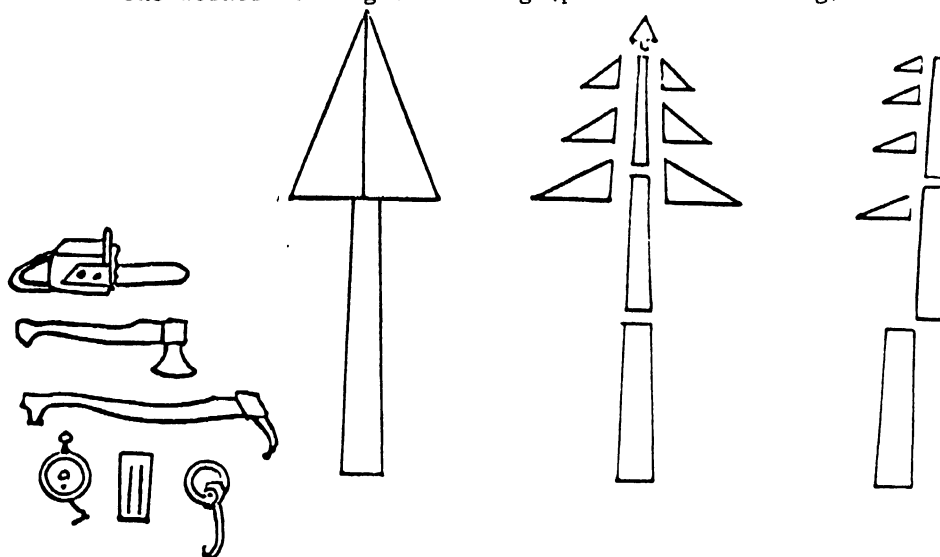
Measures to organize forest work contribute to increased safety and performance in wood harvesting and are an essential factor in the conservation of the forest and the prevention of damage to stands.



Suitable felling tools and equipment contribute to increased safety and performance in work (Photo: R. Heinrich)

### ASSORTMENT METHOD (LARGE LOGS)

One worker working on one log (power-saw delimbing)



#### Working sequence

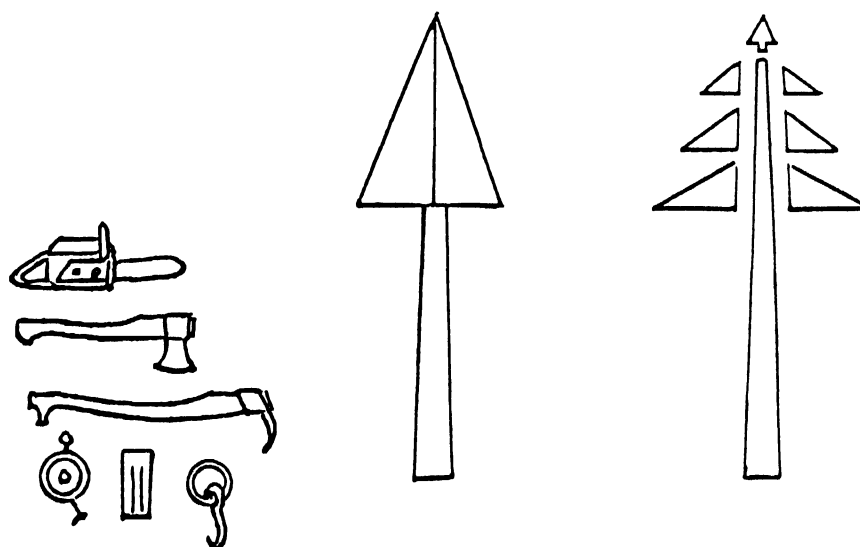
##### Tools

Power-saw  
Axe  
Peavey  
Roller tape-measure  
Wedge  
Turning hook

- |            |                            |               |
|------------|----------------------------|---------------|
| 1. Felling | 2. Delimbing on upper side | 3. Turning    |
|            | Measuring                  | Delimbing     |
|            | Sorting                    | on lower side |

### FULL-LENGTH METHOD (LARGE LOGS)

One worker working on one log (power-saw delimbing)



#### Working sequence

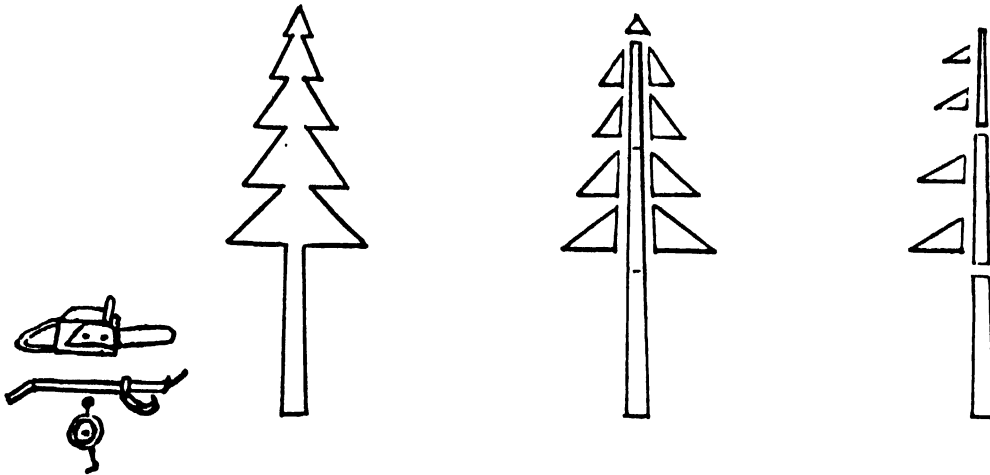
##### Tools

Power-saw  
Axe  
Peavey  
Roller tape-measure  
Wedge  
Turning hook

- |            |                            |
|------------|----------------------------|
| 1. Felling | 2. Delimbing on upper side |
|            | Measuring                  |
|            | Topping                    |

### ASSORTMENT METHOD (SMALLWOOD)

One worker working on one log (rotary delimbing with power-saw)



#### Working sequence

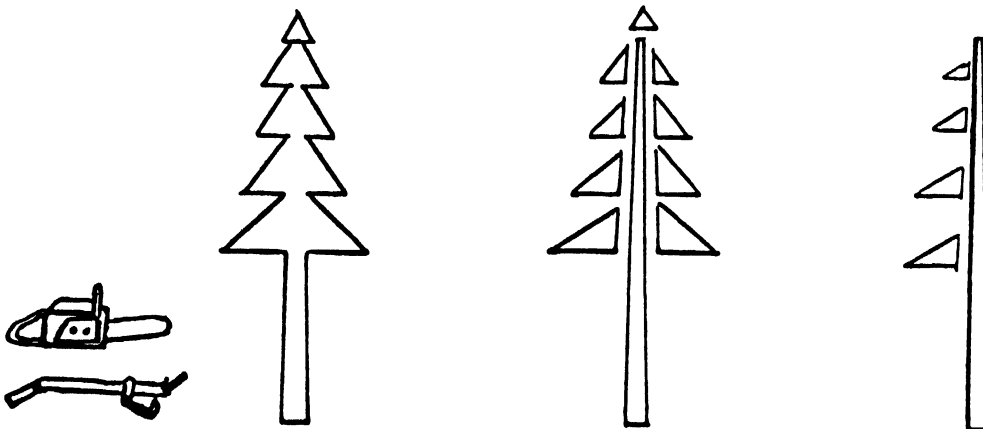
##### Tools

Power-saw  
Felling lever  
Roller tape- measure

- |            |                 |              |
|------------|-----------------|--------------|
| 1. Pruning | 2. Delimbing on | 3. Turning   |
| Felling    | upper side      | Delimbing on |
|            | Marking of      | lower side   |
|            | assortment      | Crosscutting |
|            | length          |              |

### FULL-LENGTH METHOD (SMALLWOOD)

One worker working on one log (rotary delimbing with power-saw)



#### Working sequence

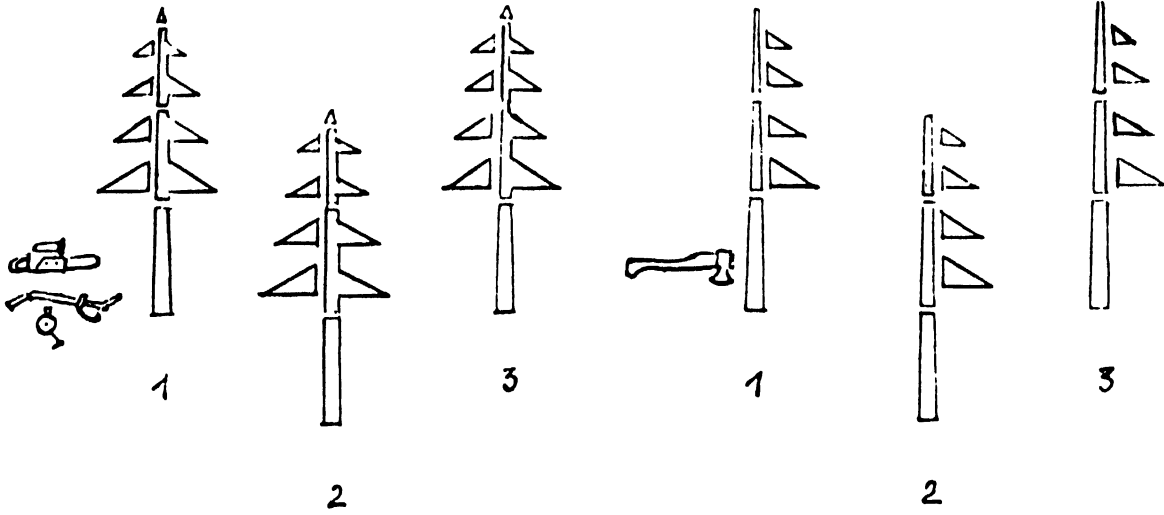
##### Tools

Power-saw  
Felling hook

- |            |                 |              |
|------------|-----------------|--------------|
| 1. Pruning | 2. Delimbing on | 3. Turning   |
| Felling    | upper side      | Delimbing on |
|            | Topping         | lower side   |

# ASSORTMENT METHOD (SMALLWOOD)

One-man cycle operation (power-saw and axe delimbing)



## Working sequence

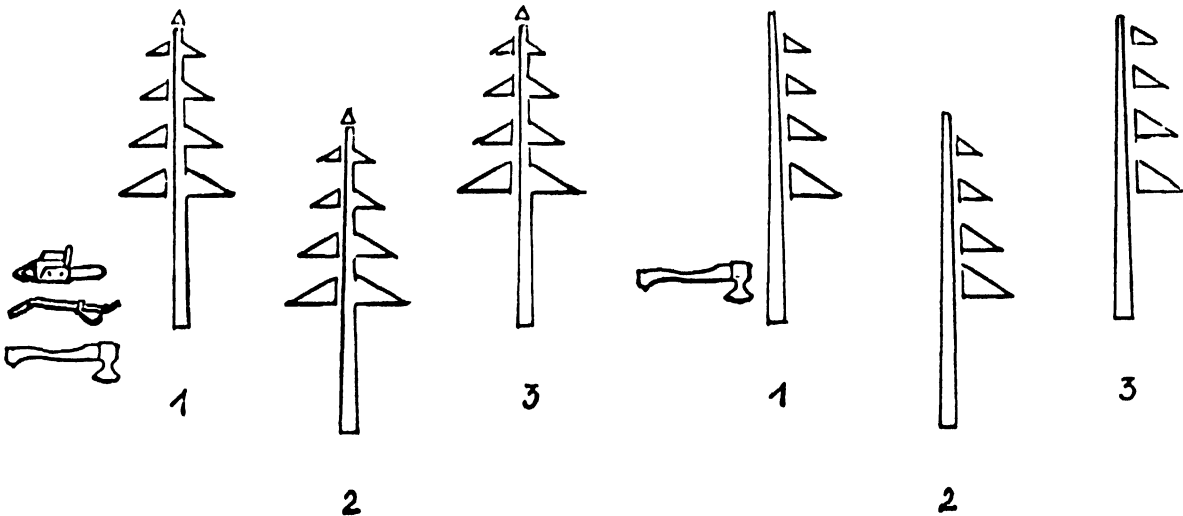
Tools  
Power-saw  
Felling hook  
Roller tape-measure

Log 1 - 3  
Pruning  
Felling  
Delimbing on  
left side  
Measuring  
Crosscutting

Log 1 - 3  
Final delimbing by axe

# FULL-LENGTH (SMALLWOOD)

One-man cycle operation (power-saw and axe delimbing)



## Working sequence

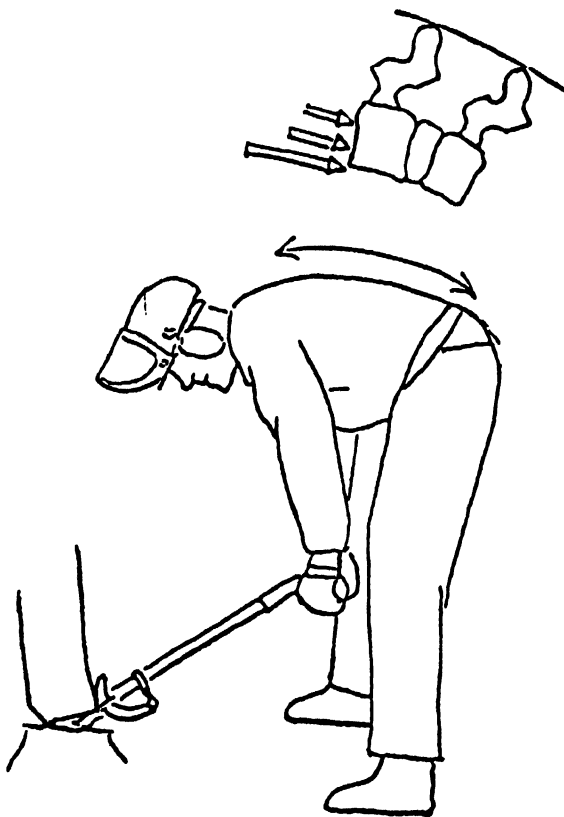
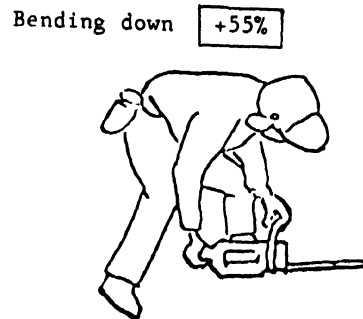
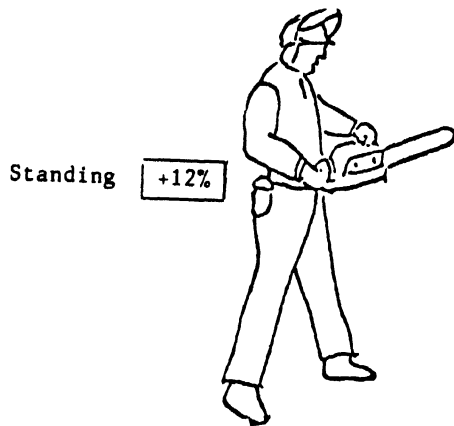
Tools  
Power-saw  
Felling hook  
Axe

Log 1 - 3  
Pruning  
Felling  
Delimbing on  
left side  
Topping

Log 1 - 3  
Final delimbing by axe

# BODY POSITION

Energy consumption in lying-down position = 100%



Vibration effect caused by power-saw operation in bent position and exposure to strain of lifting operation with twisted spine leading to damage of backbone.



10. TIMBER HARVESTING MACHINERY AND EQUIPMENT USED BY THE AUSTRIAN  
FEDERAL FOREST ENTERPRISE

Harvesting procedures are subdivided into three methods depending on the type of extraction, i.e. on whether the finished assortment, the full-length log or the whole tree is to be extracted.

The sequence of individual operations (work cycles) is called workflow. In continuous workflow felling, transporting and conversion take place simultaneously. In discontinuous workflow there are intervals between individual operations; i.e. felling is followed by transport and conversion.

10.1 Special-purpose forestry skidders

10.1.1 Smallwood skidder (machine weight up to 4 tons)

Schilter UT 5000, Holder A 60F, Steyr 8080 a

Description

Articulated, four-wheel-drive skidder with winch. Schilter UT 5000: 55 hp, all-wheel-drive, all-wheel steering; Holder A 60F: 50 hp, articulated steering, all-wheel-drive; Steyr 8080: agricultural tractor adapted for forestry work, 68 hp, Ackermann steering, all-wheel-drive; double-drum winch, Igland 5000/2, cable length: 70 - 80 m, cable diameter: 11 - 13 mm; additional equipment: radio control, lifting and lowering mechanism for the rear blade.

Harvesting techniques

Assortment method

Full-length method: continuous or discontinuous workflow (pre-felling). As a rule, felling and conversion done manually with the aid of a power-saw by employees of the forestry administration office. Number of workers depends on working conditions at the felling site. Conversion on the forest road, continuous log removal required. Skidder and operator supplied by construction and machinery yard.

Whole-tree method: combined with Strenab 35 (mechanized delimbing and crosscutting). As a rule, one feller and one skidder plus operator.

Application criteria

Suitability of the terrain to skidder operation

Thinning work using the full-length or whole-tree method planned so as to avoid the growing season. During growing season, work is confined largely to severance and light final cutting.

## Performance

Assortment and full-length method

2.0 - 2.5 m<sup>3</sup>/hr worked

Whole-tree method

14 - 16 trees/hr worked

1.5 - 2.5 m<sup>3</sup>/hr worked

## Extraction costs

AS 1/ 380/hr (US\$ 22.35/hr)

Assortment and full-length method

AS 150 to 190/m<sup>3</sup> (US\$ 8.82 to 11.18/m<sup>3</sup>)

Whole-tree method

AS 150 to 250/m<sup>3</sup> (US\$ 8.82 to 14.70/m<sup>3</sup>)

### 10.1.2 Heavy-wood skidder

#### a) Machine weight: 4 - 7 tons

Kockum KS 821 (80 hp), KS 82 (117 hp)

## Description

Articulated four-wheel-drive skidder with winch, all-wheel-drive articulated steering; double-drum winch; range: 70 m with a cable diameter of 16 mm; 80 m with a 15 mm cable, and 110 m with a cable thickness of 14 mm.

## Deployment technique

Assortment method

Full-length method (as with light-weight skidder).

## Application criteria

Suitability of the terrain for skidder operation.

Minimum daily output for successive runs in immediate vicinity.

## Performance

5 - 6 m<sup>3</sup>/hr worked

1/ AS = Austrian schilling. 1 US\$ = 17 AS.

Extraction costs

AS 480/hr (US\$ 28.23/hr)  
AS 90 to 100/m<sup>3</sup> (US\$ 5.29 to 5.88/m<sup>3</sup>)

b) Machine weight: over 7 tons

CAT 518 (125 hp), Clark 667 (152 hp)

Description

Articulated four-wheel-drive skidder with winch, all-wheel drive articulated steering, single-drum or double-drum winch; range: 70 - 80 m with cable diameter of 16 mm, and 50 m with cable diameter of 18 mm.

Deployment technique

As with 4 - 7 ton skidder.

Application criteria

As for 4 - 7 ton skidder.

Performance

8 m<sup>3</sup>/hr worked

Extraction costs

AS 550/hr (US\$ 32.35/hr)  
AS 80/m<sup>3</sup> (US\$ 4.70/m<sup>3</sup>)

10.1.3 Forwarder

a) For smallwood (thinnings)

Kockums 8431

Description

All-wheel-drive, 3-axle forwarder, 128 SAE hp, equipped with special long-jib crane with 9.5 m reach; pay-load: 9 tons.

Deployment technique

Assortment method, used in thinning work to remove logs after preliminary extraction as far as the skidding trail, or for the extraction of assortments of light wood in final harvest work; featuring radio-operated, light gauge draw-winch.

### Application criteria

Up to 40% gradient for downhill extraction, and as much as 25% for uphill extraction; forwarding distance: up to 1.5 km.

### Performance

6 - 8 m<sup>3</sup>/hr worked

### Extraction costs

AS 590/hr (US\$ 34.70/hr)  
AS 85 to 110/m<sup>3</sup> (US\$ 5.00 to 6.47/m<sup>3</sup>)

The performance and extraction costs are determined not so much by the transport distance as by the number of different assortments to be stored separately.

#### b) For heavy wood (final harvest)

Kockums 875 (167 SAE hp), Kockums 850 (156 SAE hp)

### Description

All-wheel-drive, 3-axle forwarder, equipped with 10 ton crane with 10-m reach; payload: 14 tons.

### Deployment technique

Assortment method: assortments stored separately.

### Application criteria

Up to 40% gradient for downhill extraction, and as much as 25% for uphill extraction; extraction distance up to 3 km.

### Performance

8 - 18 m<sup>3</sup>/hr worked

### Extraction costs

AS 670/hr (US\$ 39.41/hr)  
AS 80 to 100/m<sup>3</sup> (US\$ 4.70 to 5.88/m<sup>3</sup>)

The performance and extraction costs are determined not so much by the transport distance as by the number of different assortments to be handled and stored separately.

## 10.2 Cableway equipment

### 10.2.1 Mobile tower units

#### a) Small mobile tower units

Koller K 300

#### Description

Agricultural tractor 70 hp (50 kw) with 3-point hydraulic linkage (lifting power: 1 700 kg) as base unit; equipped with 7 m frame tower (designed to fold down over the top of the operator's cab for transport). The tower includes an Igland double-drum cable-winch with power take-off (mainline and skyline). Koller automated cable crane carriage (SKA 1.0 ton).

#### Deployment technique

Assortment method: felling and conversion manually with the aid of a power-saw by employees of the forestry administration office, also in intermediate extraction as unit loads of between 0.3 and 0.5 m<sup>3</sup>. One winch operator and one choker man from construction and machinery yards. Continuous extraction required. Cable route determined by construction and machinery yard, with subsequent selective on-site marking by the forestry administration office. Cable route spacing: 25 - 35 m.

Whole-tree method: each tree delimbed to a height of 2 m manually using a power-saw. After felling, the trees are pulled at an acute angle to the mainline and extracted. The winch operator runs both the cable unit and the follow-up unit required for lateral skidding. The wood is stored in accordance with the requirements of the conversion machine. Cable route spacing: about 15 m.

#### Application criteria

Uphill transport only; transport distance 300 m; minimum gradient 20% to ensure sufficient gravity pull to bring the crane carriage back down the hill. Supports may be added as required.

Applicable for the intermediate extraction of thinnings and light final harvests, and to the extraction of damaged wood, provided that the volume output is not too great. During the growing season, only the assortment method is used so as to avoid damaging other trees. During other seasons the whole-tree method is used for thinning.

It is not practicable to store more than two different assortments separately. Measuring may be carried out in the forest or when loading the logs on to trucks.

#### Performance

30 to 65 assorted pieces/cable hr

15 to 25 trees/cable hr

Erection time (erection and dismantling using two men):

1 to 4 hrs, depending on the number of supports.

### Extraction costs

AS 700/cable hr (US\$ 41.18/hr)

Including dragging  
vehicle

AS 800/cable hr (US\$ 47.06/hr)

Hinteregger Miniurus

### Description

Single-axle trailer with VW industrial engine as the base unit; attached 5-m mobile tower; 3-drum design (mainline, skyline, haul-back line). Koller automated cable crane SKA 1.0.

### Deployment technique

See Koller K 300.

### Application criteria

The third cable drum makes this model applicable for uphill and downhill transport (provided the terrain is not too steep) as well as for work in flat terrain. Extraction distance: 300 m. Supports may be added as required. Otherwise see Koller K 300.

### Performance

Approx. 60 assort.pieces/cable hr

Approx. 20 trees/cable hr

Erection time (erection and dismantling require two men):

Up to 6 hours depending on the number of supports and whether uphill or downhill extraction is required.

### Extraction and storage costs

AS 800/cable hr (US\$ 47.06/hr)

For downhill extraction (terrain not too steep) additional costs of 20 to 25% over uphill work, because of the second man needed to pull out the cable.

Combination thinning unit OBF 1/ Mauko

### Description

Twin-axle truck as the base unit; attached 8.5-m mobile mast (8.5 m including height of vehicle); double-drum winch (main cable, hauling cable); crane attachment designed for use with either a grab processor Strenab 35 or a roundwood grapple. Koller automated cableway crane SKA 1.0.

### Deployment technique

Assortment method: see Koller K 300, but with cable route spacing of 25 m.

Whole-tree method: each tree is manually delimbed to a height of 2 m. After felling, the trees are dragged at an acute angle to the main cable and extracted. Cable route spacing: approx. 15 m.

The winch operator runs both the cable unit and the crane with attached processor Strenab 35. The Strenab 35 is designed for mechanical delimbing and crosscutting. The correct length is measured electronically; five different settings are possible. Diameters are measured manually.

### Application criteria

See Koller K 300.

Supports are required for extraction distances of over 150 m. The use of supports elevates the skyline, thus reducing the damage to the stand when logs are brought in. During seasons other than the growing season, thinning work is done on trees up to a breast-height diameter of 37 cm using the whole-tree method.

Wood to be marketed without sorting whenever possible. Storage in two different assortments is technically possible, but expensive. Delivery to the FFE's own sawmills preferable because there the logs can be electronically measured.

### Performance

30 to 50 assort. pieces/cable hr  
12 to 16 trees/cable hr

Erection time (erection and dismantling require two men):

2 to 4 hours depending on the number of supports.

### Costs

AS 800/hr (US\$ 47.06/hr)

#### b) Medium-sized mobile tower units

OBF K 602 (for assortment extraction)

### Description

Three-axle truck (300 hp) as the base unit: attached 10-m tower; four-drum unit (mainline, skyline, haul-back line, auxiliary cable). An attachable work platform is provided for the crosscutting of assortment lengths. These are then handled and stored by means of a hydraulic crane (Fiskars 10,000).

Total weight: 21 to 22 tons, depending on equipment.

### Deployment technique

Assortment method: discontinuous workflow (the wood is converted at the felling site). As a rule, one choker man and one winch operator are required. The winch operator also piles the logs for storage using the hydraulic crane.

### Application criteria

Uphill and downhill extraction for up to 500 m. Truck access to the winch area must be provided, and any bridges must have a bearing capacity of at least 22 tons.

The mobile tower and the end tower must be anchored to sturdy trees or fresh stumps, or in a heavy rock formation. Otherwise deadman anchorage is necessary and this requires the use of an excavator.

This unit is particularly well suited to situations where the use of the assortment method is necessary (for example where young stands are located between the felling site and the winch or where there is a regeneration area or an in-growth harvest area which must be protected).

### Performance and costs

As the unit is still in use on a trial basis, reliable experience data are not yet available.

#### c) Large mobile tower units (for heavy wood)

### Description

Mobile tower unit - Steinkogl

Three-axle truck (280 - 320 hp) as the base unit; attached 14.6-m tower; 5-drum cable winch (main line, skyline, haul-back line, auxiliary cable, erection cable); newer units are also available with six drums (mainline, skyline, haul-back line, auxiliary cable and two drums for lateral yarding).

Total weight: 24 tons.

Steyr KSK 16

Three-axle truck (280 - 320 hp) as the base unit; attached 17.4-m tower; 5-drum cable winch (mainline, skyline, haul-back line, auxiliary cable, erection cable).

Total weight: 34.5 to 36 tons (in four-axle design).

Koller K 800

Three-axle truck (150 hp) as the base unit; attached 11-m tower; 5-drum cable winch (mainline, skyline, haul-back line, auxiliary cable, erection cable); hydrostatic drive.

Total weight: 14 tons.



### Deployment technique

Generally full-length method; occasional use of whole-tree method in cases where the terrain conditions at the felling site are bad, or in deep snow; delimbing and conversion manually using a power-saw at the felling site. Cable extraction in combination with skidder. Continuous workflow (in winter or at sites which are either very small or in steep terrain) or discontinuous workflow (advance felling, generally during the summer months at large sites and under favourable terrain conditions; the wood remains on site after felling).

If lateral yarding over a distance of up to 35 (40) m is planned, the trees are felled off the skyline route (as a rule, one choker man is required). However, if the yarding distance is over 40 m (only when absolutely unavoidable), felling is done toward the main cable. Long yarding distances require two workers to draw the load attachment cable and chokers.

As a rule, felling and conversion are done manually with a power-saw by employees of the forestry administration office. The number of workers depends on the conditions at the felling site (conversion manually by power-saw on forest road, skidding and storage by skidder). Minimum space requirement is three times the length of the tree; continuous extraction is required. Cable unit operator, follow-up unit operator and choker man and supplied by the construction and machinery yard.

### Application criteria

Downhill and uphill extraction for distances of up to 500 m. Truck access to the winch must be provided; bridges on access route must have adequate bearing capacity.

The mobile tower and the end tower must be anchored to sturdy trees or fresh stumps, or in a heavy rock formation. Otherwise deadman anchorage is necessary, and this requires the use of an excavator.

Supports can be added. For steep downhill work, a flat landing is required, or failing this, lateral extraction.

"Standard" trees may be left standing.

Raised-head transport: it is not always possible to use this technique when there is a young stand below the skyline which might be damaged. The same applies for natural regeneration and light felling during the vegetative period.

Minimum volume requirement:

Uphill extraction: 200 m<sup>3</sup> (without supports 150 m<sup>3</sup>)  
Downhill extraction: 400 m<sup>3</sup> (without supports 300 m<sup>3</sup>)

### Performance

9 to 12 m<sup>3</sup>/cable hour

(maximum 25 m<sup>3</sup>)

10 to 12 trees or logs/cable hour

Erection time (erection and dismantling using three men):

Uphill extraction: 1 to 2 days

Downhill extraction: 2 to 3 (4) days

per support: 1 to 3 hours

### Costs for extraction, dragging and storage

AS 150 to 300/m<sup>3</sup> (US\$ 8.82 to 17.65/m<sup>3</sup>)

#### 10.2.2 Other cable units

##### a) Small, radio-controlled ground-type cable winches

Nordfor, Theissen FS 100

### Description

Single-drum winch (15 hp), sheet steel enclosure; Kohler engine 15 hp; 12 m long, 6-mm diameter cable and 90 m long, 8-mm diameter cable.

### Deployment technique

Assortment method, thinnings.

Broadleaved species: generally two-man teams (one feller, one winch operator) for felling and conversion manually by power-saw, intermediate extraction to the skidding trail.

Coniferous wood: generally three-man teams (two fellers required because of greater amount of delimbing work, one winch operator).

Planning of the skidding trail by the construction and machinery yard with subsequent marking-out of elite trees by the forestry administration. Spacing between skidding trails: 50 m; width of skidding trails: 3.5 m. Extraction from the skidding trail to the road by forwarder.

### Application criteria

The skidding trail must be adequate for use by the forwarder with uniform terrain and easy walking conditions.

## Performance

Felling, conversion and intermediate  
extraction to the skidding trail by the team  
1.8 m<sup>3</sup>/hr

Extraction with forwarder  
6 to 8 m<sup>3</sup>/hr

## Costs

Winch and winch operator	AS 3 000/hr	(US\$ 176.47/hr)
Feller	AS 190/hr	(US\$ 11.18/hr)
Felling, conversion and intermediate extraction to the skidding trail	AS 270 to 310/m <sup>3</sup>	(US\$ 15.88 to 18.24/m <sup>3</sup> )
	AS 380 to 420/m <sup>3</sup>	(US\$ 22.35 to 24.70/m <sup>3</sup> )
Extraction with forwarder	AS 100 to 140/m <sup>3</sup>	(US\$ 5.88 to 8.24/m <sup>3</sup> )

The performance and extraction costs are determined not so much by the transport distance as by the number of different assortments to be stored separately.

### b) Long-cable winch units - sledge winch

#### Description

Gantner, models USW 60, USW 80

Lightweight (aluminium cast rims) sledge winch: Diesel engine 60 and 80 hp respectively; one-or two-drum design (suitable for all terrains), parabolic and cable groove pulley; automated cableway crane. Koller SKA 2.5.

Nesler, models MSA 2, MSA 3

Sledge winch: VW industrial engine, 39 hp; for MSA 3 model, optional 50 or 67 hp; generally in single-drum design (gravity return). MSA 2: cable length 1600 m with a diameter of 9.5 mm; tensile strength 200 kp. MSA 3: cable length 2600 m with a diameter of 10.5 mm; tensile strength 3000 kp.

#### Deployment technique

Assortment method: Determination of cable route, marking of support anchor and end-mast trees by experts of auxiliary technical unit. Felling and conversion normally done manually by power-saw by employees of the forestry administration office. The auxiliary technical unit generally supplies one winch operator, one choker man and one man at the unloading point. In cases where the lateral yarding distance is long or where the terrain is particularly difficult, two choker men may be required for a felling site. Where space at the unloading point is limited or for short extraction distances and heavy wood, a second man may be required for unloading. Continuous extraction of the wood is necessary.

### Application criteria

Guideline for required minimum volume: 1 m<sup>3</sup> wood for each metre of extraction distance (less for long distances).

This technique is applicable under any terrain conditions but because of economic considerations it is advisable to restrict its use to assortment extraction over long distances (55 m and over), where regeneration and young stands must be protected.

For gravity operation minimum gradient of 20% is required to ensure return of carriage down the hill.

### Performance

4 to 7 m<sup>3</sup>/cable hr

Erection time (erection and dismantling using three men):

2 to 5 days

Time per support 4 hours

### Costs

AS 260 to 450/m<sup>3</sup> (US\$ 15.29 to 26.47/m<sup>3</sup>)

#### c) Cable units for heavy wood

Cable winch - Steinkogl

### Description

Twin-axle truck (200 hp) as base unit: cable winch, including two large cable drums (hauling and haul-back lines) with differential lock, two additional cable drums for the auxiliary and erection cables.

### Deployment technique

Full-length or whole-tree method.

Combined cable and skidder extraction, generally discontinuous workflow (advance felling after selection of hill and valley anchorage).

Felling, conversion, space requirements and team composition are the same as described for the large mobile tower units. Continuous extraction required.

### Application criteria

Downhill and uphill extraction for an extraction distance of up to 600 m (technically possible to extract over a distance of 700 m). The machinery is placed beyond the danger zone, so that this unit is suitable for use on extremely steep slopes. The minimum quantity of wood which can be economically extracted per installation is 300 m<sup>3</sup>.

Using a technique without skyline, that is, haulage with an endless rope, is possible only in concave terrain. With this technique the slack is taken up on the haulage cable so that the load is raised to about the height of a man for extraction. This technique cannot be used if there are young stands between the felling site and the winch which might be damaged. The technique leaves no "standards" (clear cutting only) and it is very difficult to protect any natural regeneration.

It is also technically possible to use a skyline. In this case the deployment conditions are the same as those described for the large mobile tower units.

### Performance

10 to 11 trees (logs)/cable hr  
9 to 11 m<sup>3</sup>/cable hr

### Costs

For extraction, dragging and storage

AS 180 to 400/m<sup>3</sup> (US\$ 10.59 to 23.53/m<sup>3</sup>)

Rettenback hydraulic winch

### Description

Self-propelled winch with rear-wheel drive; 135 hp; hydraulic two-drum unit (hauling line, haul-back line), automated cable crane BACO or Hinteregger GRAVIMAT 3.5 ton (all-terrain).

### Deployment technique

Full-length or whole-tree method. Combined cable and skidder or processor extraction, for a continuous workflow.

### Application criteria

Ground skidding with extraction up to 200 m with skyline (with drum carriage, extraction distance up to 1 000 m). Supports may be added as required. The unit can also be sled mounted to reach felling sites which have not been opened up by roads.

### Performance

8 to 10 m<sup>3</sup>/cable hr.

### Costs

For felling; ground skidder extraction and subsequent loading unit

AS 150 to 250/m<sup>3</sup> (US\$ 8.82 to 14.70/m<sup>3</sup>)

For felling: main cable extraction and subsequent loading unit

AS 220 to 280/m<sup>3</sup> (US\$ 12.94 to 16.47/m<sup>3</sup>)

### 10.3 Highly mechanized conversion

#### 10.3.1 For smallwood (intermediate harvest)

Strenab 35

### Description

Transport vehicle:

Articulated skidder chassis or mobile excavator Liebherr A 911 or twin-axle truck (thinning combine, Mauko, of the FFE's own design) attached special crane with conversion head on end of jib, Strenab 35 (grab processor, model 602): cutter delimbing, crosscutting work with 80 cm circular saw; studded chain advance.

### Application technique

The trees are extracted by cable or skidder to the road or skidding trail, where they are temporarily stored within reach of the crane.

The Strenab 35 delimbs and crosscuts mechanically. Lengths are measured electronically; five settings can be programmed. The log diameter is measured manually. Mauko: continuous workflow.

### Application criteria

Strenab 35 can be used to convert logs with diameters up to 37 cm at breast height. Volume of the logs should not be less than 0.1 m<sup>3</sup>. For best utilization of the machine, a buffer volume of at least 200 m<sup>3</sup> should be available at the operating site.

(For Mauko description see 10.2.1 a).

### Performance

Discontinuous workflow

50 to 70 trees/hr

100 to 150 assort. pieces/hr

Continuous workflow (Mauko)

12 to 16 trees/hr

30 to 50 assort. pieces/hr

### Costs

Discontinuous workflow

AS 700/hr (US\$ 41.18/hr)

Continuous workflow (Mauko)

AS 95 to 140/m<sup>3</sup> (US\$ 5.59 to 8.24/hr)

For felling, extraction and conversion

AS 800/hr (US\$ 47.06/hr)

10.3.2 For heavy wood (final harvest)

Strenab 60

### Description

Articulated skidder chassis (CAT 518 or Clark 668) with added weighting; attached special crane with conversion head on the end of the jib, Strenab 60 (grab processor for heavy wood, model 602); cutter delimbing, cutting-off work with 140-cm circular saw; studded chain advance.

### Application technique

The trees are extracted by cable or skidder to the road or skidding trail, where they are temporarily stored within reach of the crane. Continuous workflow after large cable winch operations.

The Strenab 60 delimbs and cuts to length mechanically, lengths are measured electronically; five settings can be programmed (max. length 11 m). The log diameter is measured manually. Continuous wood extraction required.

The first two metres of the tree are delimbed manually by power-saw so that the tree can be more easily handled. Heavy root collars are an obstacle and must be removed during the felling process.

Immediate conversion is possible only with wood which is extracted butt end first. For this reason narrow felling strips of no more than 500 m in length are particularly practical. Wood which is extracted top end first must be delimbed before it can be converted. This second working operation reduces performance. In wide felling strips, where a large portion of the wood is extracted top end first, continuous processor conversion is not possible.

### Application criteria

The Strenab 60 is suitable for processing wood up to a maximum breast height diameter of 62 cm. Thicker trunk sections near the ground must first be cut away by power-saw.

In areas where a large percentage of the wood is broadleaved, processor conversion is impractical, because the highly mechanized method does not permit the conversion of high-grade timber. The processor is not able to transport the trees over more than a 10% uphill slope. The whole-tree method cannot be used in areas where the nutrient balance of the soil may be endangered (in particular in shallow dolomitic and lime soils).

The wood should be marketed without sorting whenever possible. Storage in four different assortments is technically possible but expensive. Delivery to the FFE's own sawmills is preferred as this permits electronic measuring (measurements can also be taken manually, for example when loading the truck).

### Performance

Continuous workflow

10 to 15 m<sup>3</sup>/hr

Discontinuous workflow

20 to 25 m<sup>3</sup>/hr

### Costs

AS 850/hr (US\$ 50.00/hr)

Continuous workflow

AS 57 to 85/m<sup>3</sup> (US\$ 3.35 to 5.00/m<sup>3</sup>)

Discontinuous workflow

AS 34 to 43/m<sup>3</sup> (US\$ 2.00 to 2.53/m<sup>3</sup>)

The advantage of the lower conversion costs achieved working in a discontinuous operation is almost always offset by the costs of bringing the trees from the cable unit to the conversion area. For this reason, continuous workflow is recommended in cable extraction.

### SUMMARY

Before machines and vehicles can be used for forestry work in mountainous terrain, the operating area must first be opened up with a network of forest roads. For the mechanized extraction techniques in common use today in consolidated holdings, a road density of between 25 and 30 m/ha is sufficient.

The use of machinery must be based both on a suitable 10-year plan and on a detailed harvest or operation plan for each calendar year. The 10-year plan coordinates the work volume with the capacity of the enterprise. It takes into account the development of work productivity and establishes target data for mechanization and streamlining measures.



A detailed annual harvest and deployment plan sets out the individual harvest areas and felling sites. It also ensures the best possible utilization of the available work force and machines throughout the year in accordance with the 10-year plan. The detailed harvest plan identifies, for each felling site, all factors related to silvicultural requirements, harvesting techniques, organization and marketing.

The foreman is given a sketch showing all important details required for the execution of the work.

The economic deployment of machinery is possible only if the work is properly organized. The duties of each employee and the sequence of the harvesting operations must be clearly defined to ensure a smooth workflow.

Successful operations depend on the distribution of work on the basis of a performance-oriented bonus system satisfactory to both employer and employee. Work targets should, on the one hand, be based on ergonomic findings and, on the other, should help to establish performance standards based on practical experience.

Company-owned machinery yards should operate as a profit centre on a cost performance unit basis, just as those of independent contractors would.

Cost and performance data are indispensable for the establishment of any kind of objective success criteria. These data are gathered by the construction and machinery yard on the basis of cost accounting for each job undertaken.

Each wood harvest is concluded by a critical examination of the results and consequences of the work completed. The results of the examination are then available for the planning and execution of future jobs.

Further development of available technologies depends largely on detailed cost calculations. These are used to weigh the various factors of the individual harvesting phases. The cost figures taken in combination with time observations show up the weaknesses of the various techniques. It is the duty of the foremen to watch for such weaknesses and to try to remove bottlenecks whenever possible. Continuous improvement in organization and workflow should prove effective in combating ever-rising costs.

In the mechanization of wood harvesting there are still many areas in which improvements are possible. It will be a rewarding task in the years ahead to pinpoint these areas and to institute the appropriate improvements.



Steyr four-wheel-drive tractor with logging trolley being  
utilized to skid logs to roadside (Photo: Steyr)

## TREE FELLING IN MOUNTAINOUS CONIFEROUS FORESTS, TECHNIQUES, PRODUCTION AND COSTS

by

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In general, tree felling can be carried out on a continuous basis, with some cut each year, or on an interrupted basis over a period of several years, depending on the demand for roundwood. The volumes felled should be based on the average annual increment.

The planning and organization of felling operations should take into consideration the following:

1. Preparation
2. Provision of tools
3. Work clothes and protective equipment
4. Felling
5. Delimbing
6. Debarking
7. Conversion
8. Accident prevention and health protection.

### 1. PREPARATION

In preparing for timber harvesting, the following conventional forest rules apply:

- Fell only when market conditions are favourable. Thin first and clear older stands.
- Fell badly shaped trees and understocked stands first.
- Instead of large clearcuts, preference should be given to strip and selection cutting (above all, take into account the latest silvicultural findings).

Before felling, determine whether under existing forestry legislation or any other legal provision, felling must be reported to the competent authority.

The time of year in which felling is carried out is of particular importance for the timber quality. Whereas in former times, especially in mountainous areas, felling was possible only in summer, it can now be done in most cases in winter as well, thanks to modern forest roads, machines and working methods.

Felling at any time of the year requires well stabilized forest roads that can be used even in bad weather. Some countries have a definite rainy season, a factor which must be considered in planning.

It is necessary either to supply timber to industry on a continuous basis or to have adequate storage yards in order to meet the demand during periods of bad weather.

In countries with definite summer and winter seasons it makes a great difference when felling is planned.

#### Advantages of summer felling

- The work is easier and pleasanter.
- It is safer, since the ground is not frozen and the tools are not cold.
- The worksite can be reached more easily and more quickly.
- The day is longer, so the working time can be used more efficiently, especially with regard to piece-rate jobs.
- The timber can be debarked easily.
- The timber dries quickly and therefore is lighter and easier to skid.

#### Disadvantages of summer felling

- The timber, especially on sunny slopes, dries too quickly and develops cracks.
- When stored for longer periods at the felling site, the timber quality deteriorates from fungal attacks, blue stain in pines, or cracks.
- The timber must be debarked at once or removed from the forest within a very short time.
- It is often attacked by beetles.

#### Advantages of winter felling

- The timber is of superior quality, since it is felled when the sap is low.
- Debarking at the felling site is not necessary, so machines may be used.
- Attacks of fungi and insects do not pose a problem.
- Labour is easier to obtain, since a great deal of farm work is interrupted in winter and more forest workers are available.
- The forest soil is protected so that natural regeneration may take place.

#### Disadvantages of winter felling

- All advantages of summer felling are reversed.
- Owing to the high accident risk, solid shoes and other costly protective equipment are extremely important.

Felling can be paid on an hourly rate basis, or on a piece-rate or premium basis. Hard physical work, such as salvage logging after a disaster, is paid at hourly rates. Most felling is paid on a piece-rate basis. For special work, such as the removal of hold-over trees from new growth, a premium may be paid.

Standard data or performance charts for forestry work make it possible to determine the number of hours needed to fell a cubic metre of timber. Different factors, such as the season, stump area characteristics, terrain, soil, diameters and heights of trees, branchiness, shape, etc., should be measured as accurately as possible.

Working conditions which make the work more difficult are given time allowances in the charts. The total of the time allowances shows the total time input estimates per cubic metre. To calculate the rate on a piece-work basis, the time input is multiplied by the standard hourly wage plus 25 percent. (See example in Appendix A.)

## 2. TOOLS

In recent decades, research and training have resulted in fundamental improvements in forestry tools. Trees were traditionally felled with axes, delimbed, debarked and finally cut to individual assortments. This type of logging was practised in the Alps until as late as 1946. The double-handled crosscut saw, developed in the 18th century, remained basically the same until 1940. Even though power-saws were used during both world wars, the real breakthrough did not come until 1956/57. Today, the one-man power-saw, the single most important logging tool, is king of the forest. Satisfactory work performance requires satisfactory equipment.

### Equipment for a two-man team

- 1 power-saw with maintenance tools
- 1 5-litre fuel can
- 1 2.5-litre can for chain oil
- 2 axes - not too heavy
- 2 debarking irons if debarking work is required
- 2 peavies (turning hooks) if required
- 6 wedges
- 1 tape measure 15 m long with rewinding mechanism or a fold-up 1- to 2-m measuring stick

## 3. WORK CLOTHING AND PROTECTIVE EQUIPMENT

Job- and climate-oriented clothing improves performance and reduces accidents. Protective gear is essential to the health and safety of the worker.

The most important items of clothing and work gear are listed below:

- ventilated helmet with eye and ear protection
- underclothing (cotton), perspiration absorbing, anti-condensation material
- work shirt, luminous colour
- pullover, wool for winter
- trousers with side pockets and protective insert padding
- leather gloves for work with the power-saw
- terrain shoes with grip soles
- rain gear designed to reduce condensation and to allow freedom of movement
- work belt designed to hold tape measure, files and wedges
- leg irons for work on frozen slopes
- first-aid box complete with bandages, etc.

Special protective gear is required for work done in the proximity of public roads. Warning signs with the inscription "Logging Work in Progress" must be posted. Additional equipment is required for work done in danger zones (grab tools, cables and ropes, pulleys and, in some cases, winches and tractors).

#### 4. FELLING

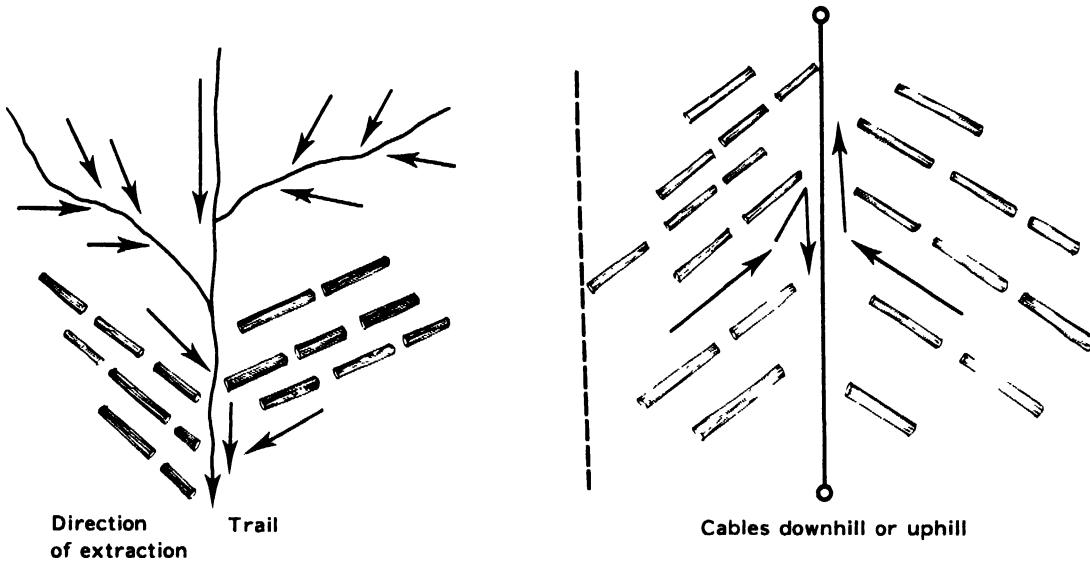
In mountainous terrain, trees must be felled uphill in order to minimize damage from the fall. The direction of felling depends on the type of extraction. For surface skidding, a fishbone pattern is used, the trees being felled outward. For cableway extraction, the reverse is used. The type of extraction must be determined first, then the type of felling.

##### Work flow

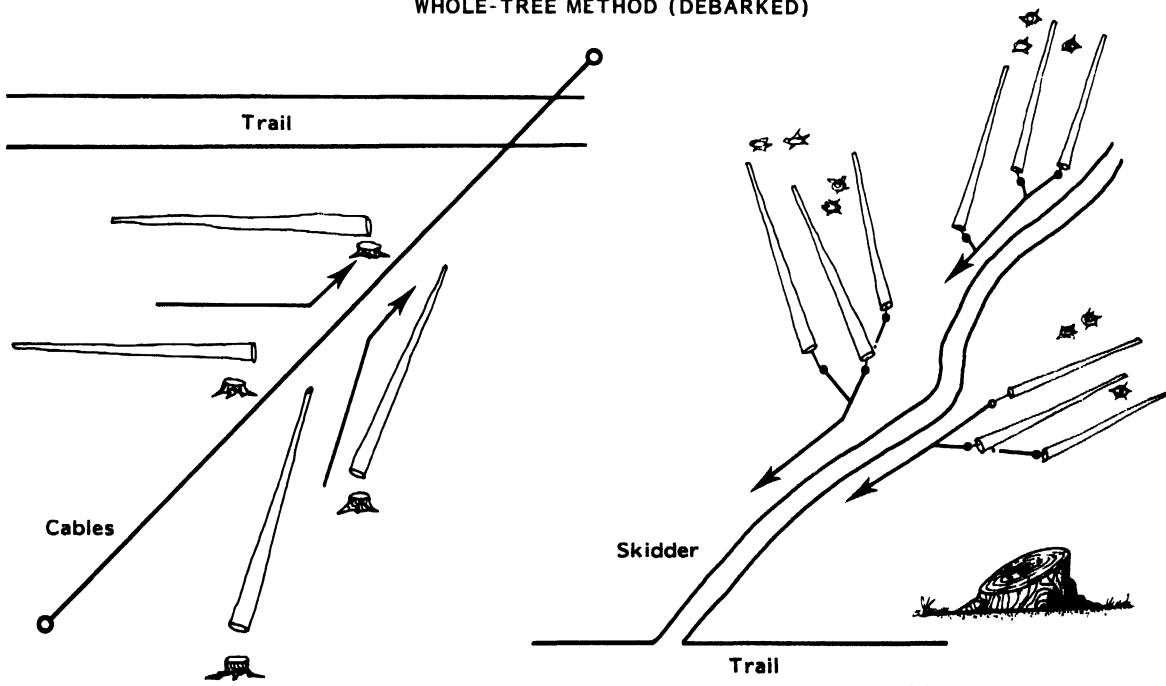
- Assignment of job (by forest owner or his deputy);  
written description of the principal characteristics of the felling site;  
determination of the felling site and type of felling (clear cuts, thinnings, etc.);  
determination of the type of skidding and extraction, indication of conversion and assortment work to be done, etc.;
- Work preparation (to be done by the competent district official);  
marking out of the wood to be felled;  
determining remuneration for forest workers, provision of vehicles, shelter, storage and maintenance of tools, conclusion of a felling agreement, documentation of all matters relevant to the execution of the work;
- Examination of the tree (to be done by forest workers);  
determination of the felling direction, tool placement;
- Clearing of the felling site;  
removal of limbs, rocks, etc., clearing away around the base of trees, ensuring the protection of young stands, determining escape route;
- Determination of the felling direction, type of extraction, protection of young stands, equipment protection and safety;
- Felling notch and root collar;
- Execution of felling cut;
- Checking of felling zone;  
First call warning, then cut;
- Wedging and toppling;
- Removal of crown.

## FELLING DIRECTION FOR VARIOUS EXTRACTION METHODS

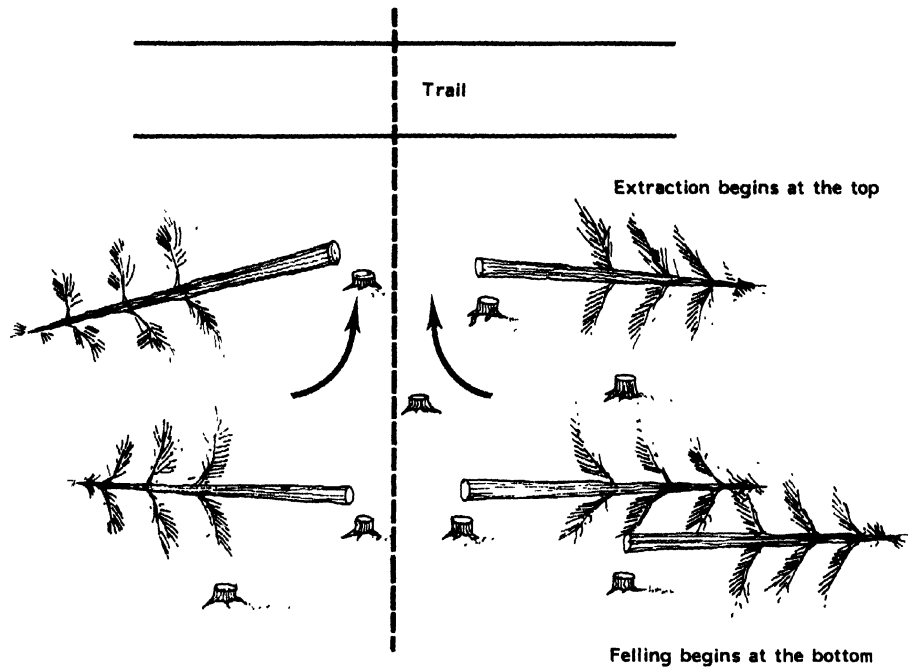
### ASSORTMENT METHOD



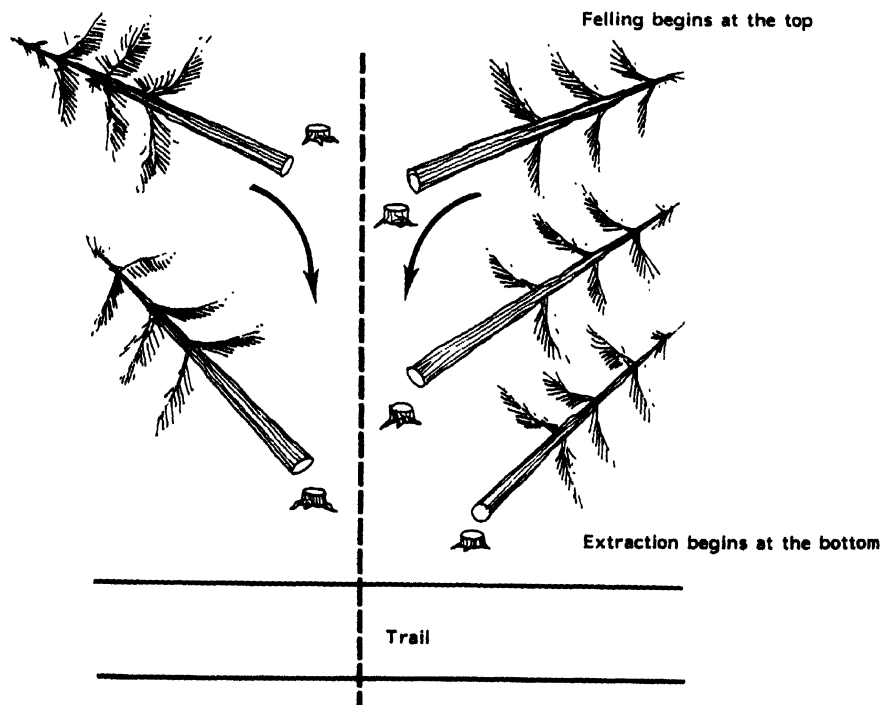
### WHOLE-TREE METHOD (DEBARKED)



WHOLE-TREE EXTRACTION - UPHILL



WHOLE-TREE EXTRACTION - DOWNHILL





### The felling notch

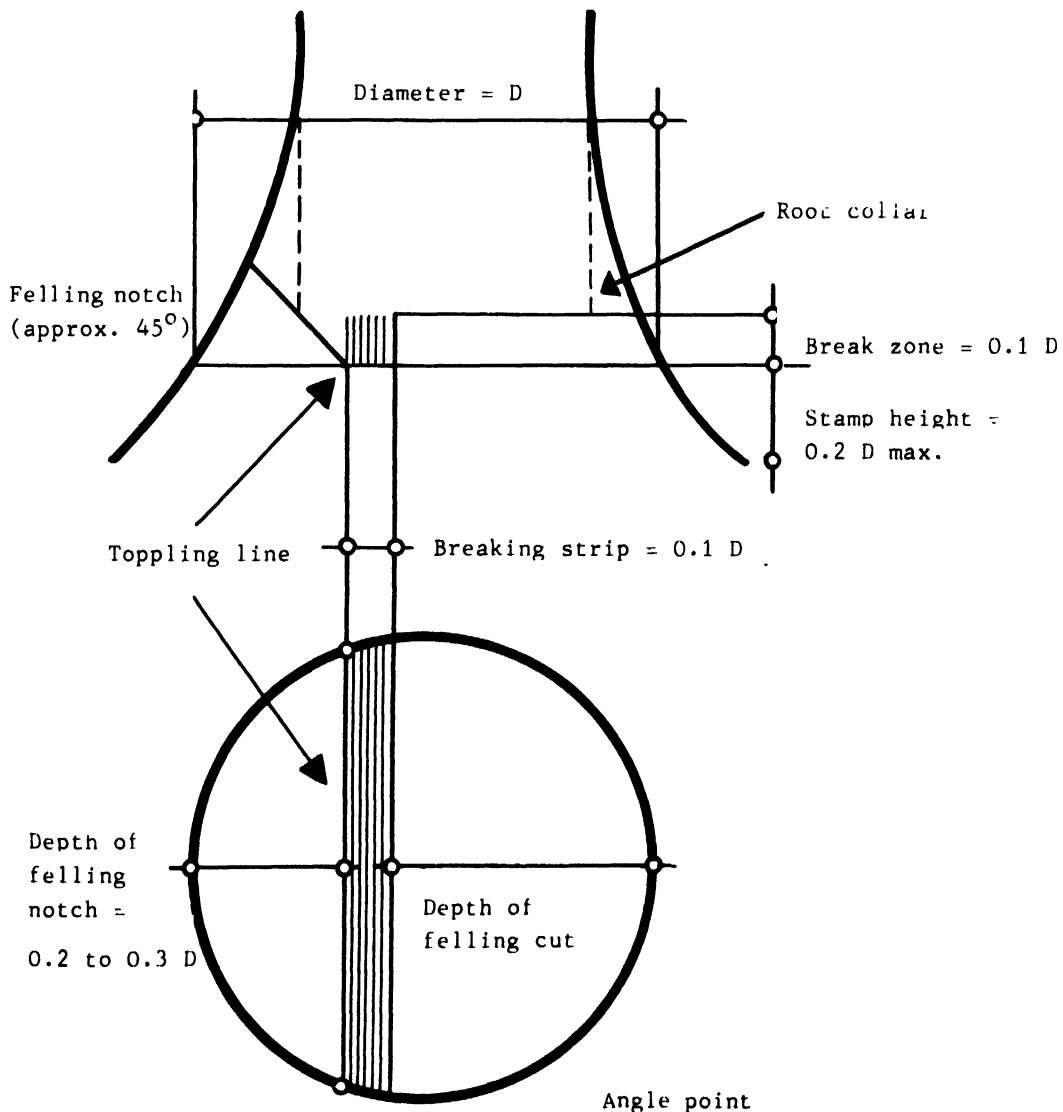
The first step in the actual felling process is to cut a notch. This determines the direction in which the tree will fall. The notch must be cut as low as possible, not higher than one fifth of the stump diameter. Stumps exceeding this height can mean  $10 \text{ m}^3$  of wood wasted for every hectare of forest harvested.

### The root collar

This is removed before felling only in large trees. More commonly, the tree is felled and the collar cut away in a subsequent operation.

### Felling cuts

Job safety depends largely on the proper execution of the felling cut. This cut should be about a tenth of the stump diameter above the base of the notch. The break line is essential. The type of felling cut depends on the diameter and the shape or lean of the tree.



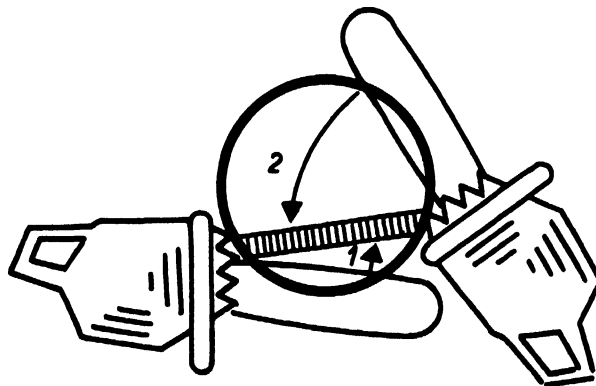
Generally, the notch is cut first and then the felling cut is made. This is reversed only for trees leaning away from the felling direction.

One vital rule applies to all types of felling work: The compression side of the tree is dealt with first, then the tension side.

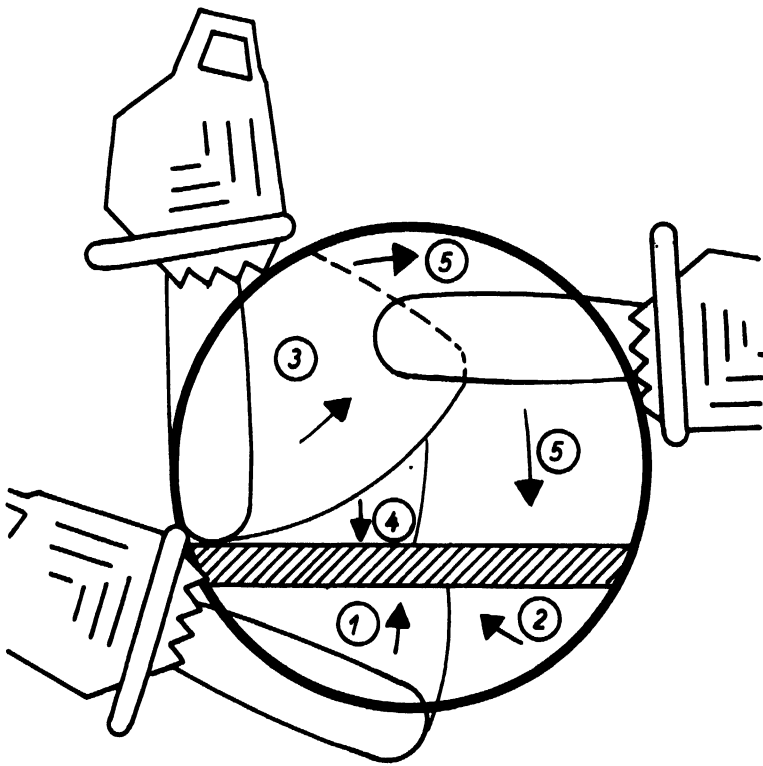
The following types of felling cut are common:

Felling cut for small-diameter trees (diameter less than the length of the power-saw blade)

Felling cut in  
a single pass



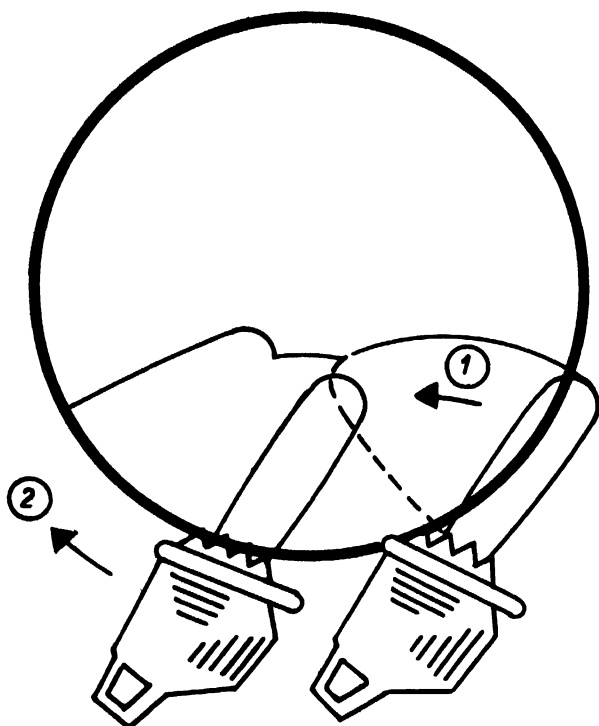
Felling cut for medium-sized trees (diameter up to twice the length of the power-saw blade)



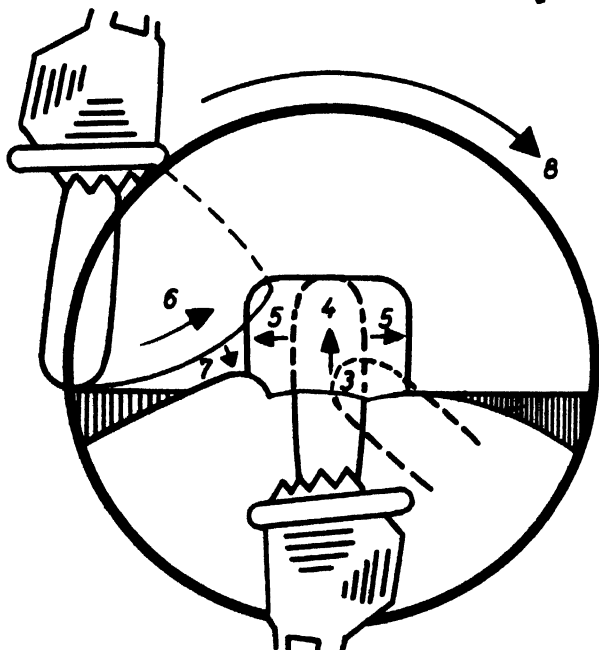
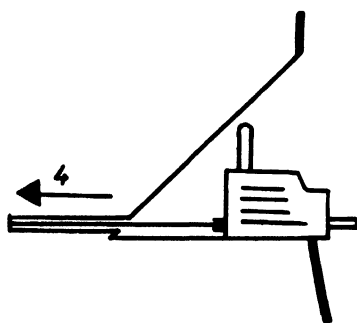
The notch and felling cuts are made from different sides

Felling cut for large trees (diameter up to 2.5 times the length of the saw blade)

The notch is cut to the depth of the saw blade

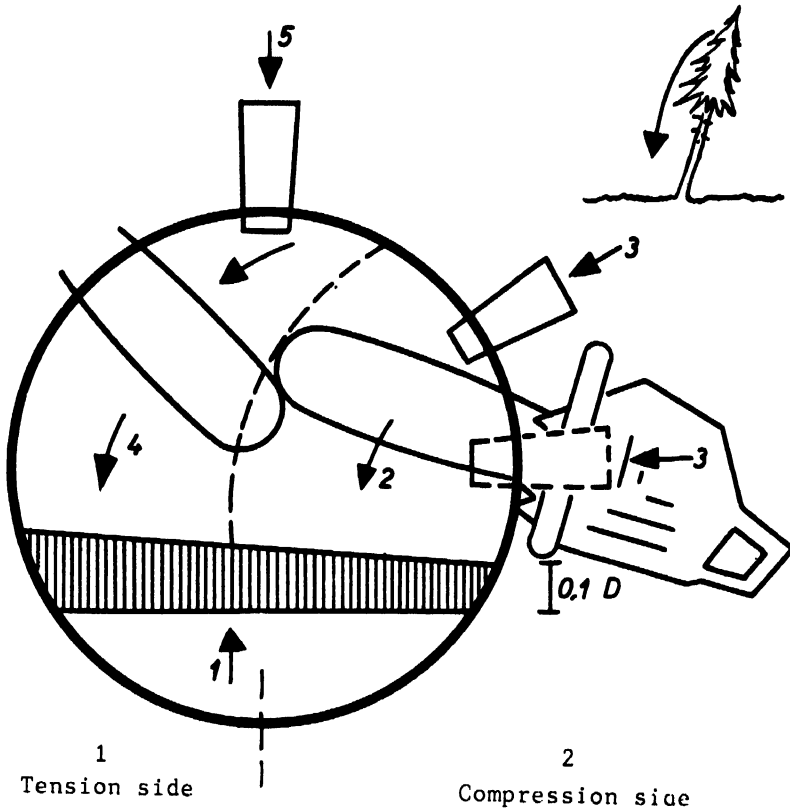


"Deep thrust"  
into the completed  
notch to cut through  
the core zone



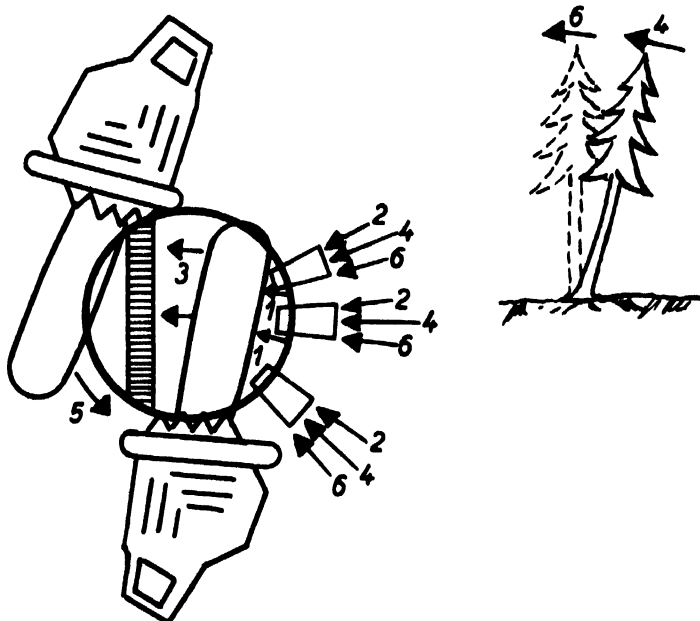
The break-line is cut  
through in the middle,  
without, however,  
breaking the "hinges".  
Next, a surface round  
cut is made with the  
aid of a wedge

Felling cut on leaning trees (tree leans to one side)



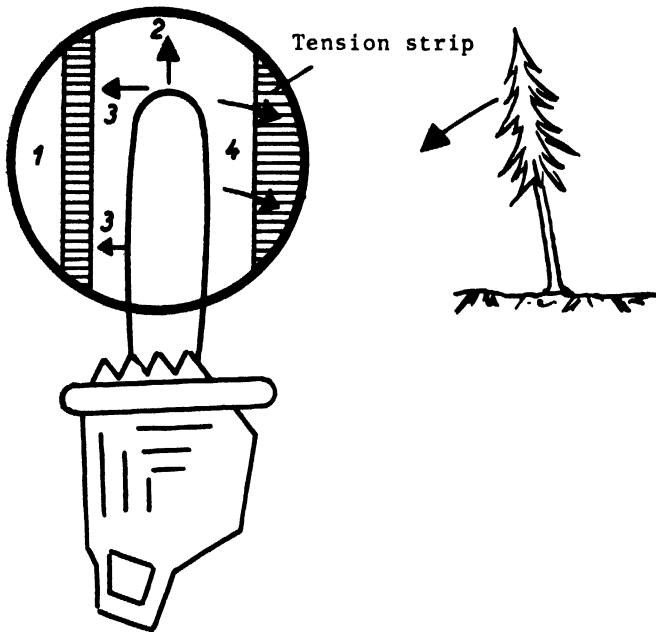
The thickness of the break-line on the compression side must be as standard. On the tension side, however, it must be correspondingly thicker. Well-timed wedging on the compression side is therefore important

Felling cut for trees leaning away from the felling direction



First execute the felling cut (pressure side) then apply wedges until tree stands straight. Finally, cut the notch and insert wedges until the tree topples

Felling cut for trees leaning in the felling direction



After cutting the notch, the felling cut is made in such a way as to leave the tension strip intact. This strip is finally cut from the inside (from the compression side)

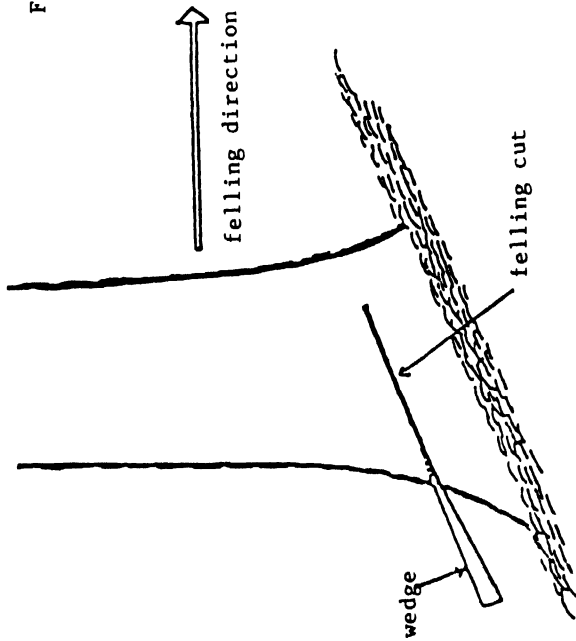
In forestry practice a combination of the six listed methods is used depending on the situation. It is not uncommon, for example, for a tree to lean at an angle and in the felling direction as well. In this case the two relevant methods must be combined.

It can be quite difficult to fell trees with a heavy crown density. In this case a method is used which permits the pulling of the tree into the stand after the felling cut has been made.

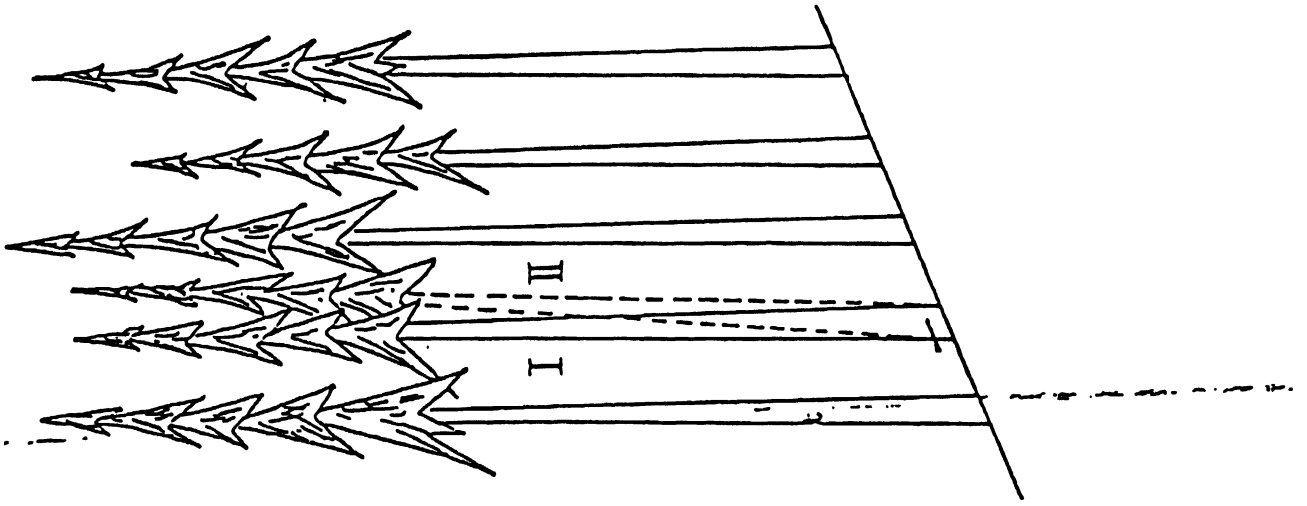
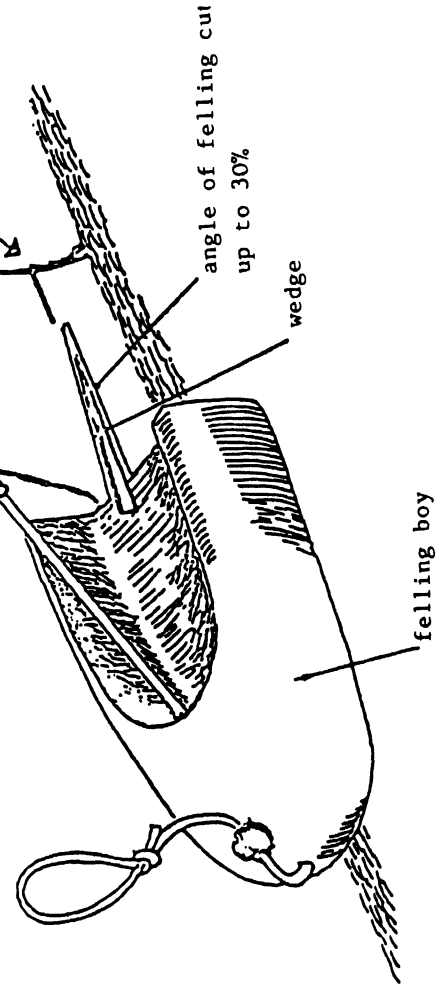
The angular cutting method can be used for trees with a diameter of up to 20 cm. A felling cut is first made on the downhill side parallel to the ground, or at an angle of about 30°. Once the cut is deep enough, a wedge is inserted and the tree is wedged up until it leans slightly in the intended felling direction. Then a counter cut is made on the uphill side about 1 cm higher than the felling cut. Once the tree is cut through, it topples over the wedge. This however requires a sufficiently steep slope.

For work done on level ground or on slopes of up to about 40%, a plastic shoe (the so-called "felling boy") is used. This permits the tree to be pulled to the ground.

Felling technique in smallwood



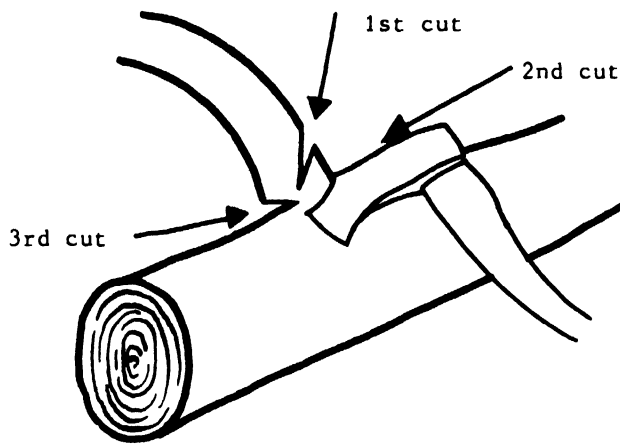
IMPORTANT!  
The counter-cut must be  
higher than felling cut



## 5. DELIMBING

The delimbing operation starts at the butt end and is carried on toward the crown. Doing it in the opposite direction would pull the branches out of the stem and reduce the timber value. Proper delimbing is a prerequisite for efficient debarking, easy skidding and better selling opportunities on the market since a better product is produced. Delimbing is carried out by use of either an axe or a power-saw. Axes should weigh from 1.0 to 1.2 kg for smallwood and 1.2 to 1.3 kg for larger material.

### Delimbing of big branches by axe



1st cut: break of branch's tension

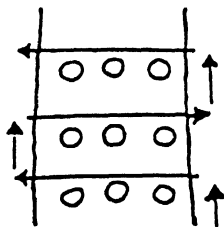
2nd cut: kerf incision

3rd cut + subsequent cuts

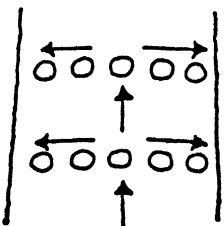
For ergonomic reasons branches with diameters of more than 2.5 cm should not be delimbed by axe. Safety requires the worker to stand on one side and work on the other side of the stem.

Larger branches require delimbing by power-saw.

### Delimbing by power-saw



lever method for  
branch diameters  
between 2.4 and 5 cm



vertex method  
for branch diameters  
above 5 cm



If required, these methods can of course be combined. In clear cuts, branches are thrown on to heaps to keep them out of skidding tracks. In single-stem harvesting and thinning operations, branches are deposited near remaining trees to protect the trees from being damaged by skidding. In naturally regenerating stands branches are piled in small stacks to leave sufficient space for seedlings. Branches and needles are natural fertilizers and ideally should be distributed evenly over the forest soil.

## 6. DEBARKING

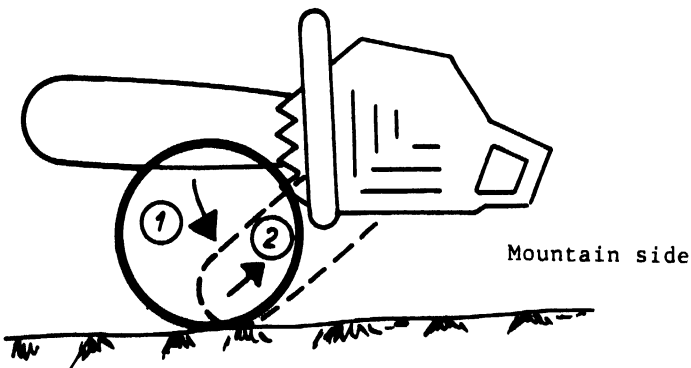
It may be necessary to debark trees at the felling site since they are skidded more easily, they dry better and they are less exposed to pest damage. However, timber is increasingly sold with the bark on and mechanically debarked at the landing or in the plant. Manual debarking accounts for about 40 percent of all felling work in Austria. It should be limited to cases where there are pest hazards such as in summer felling or to the felling of small quantities.

Mechanical debarking is economic only if it is carried out at the processing site (sawmill, papermill, processing yards). Because of the present energy situation trees are frequently not debarked but processed right away. Edgings and bark are chopped up (hogged) and either burnt or used in industry for board production.

## 7. CROSSCUTTING (BUCKING)

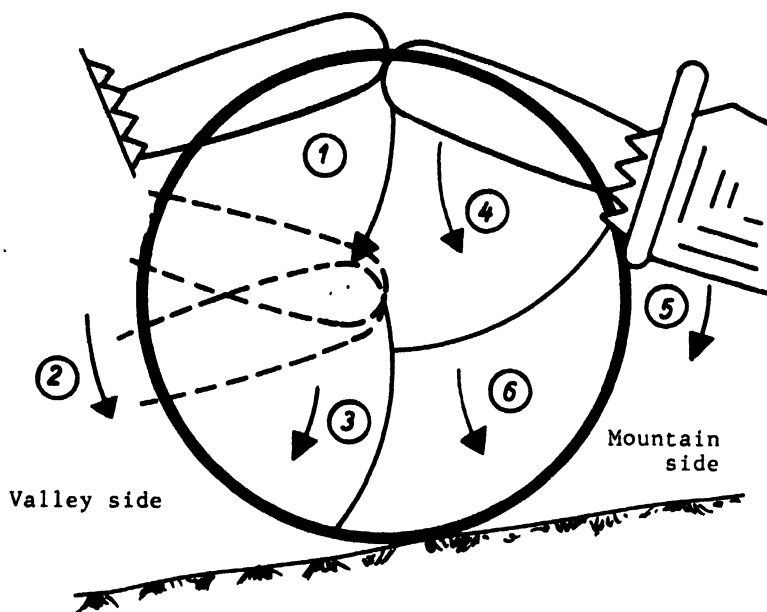
Before crosscutting can start, unhealthy parts of the stem are cut off and assortments which are in demand on the market are manufactured. Depending on diameter and position of stems the following methods are used:

Simple crosscut (stem diameter up to the length of the power-saw blade)



If working on slopes,  
working position is  
always on mountain  
(upper) side

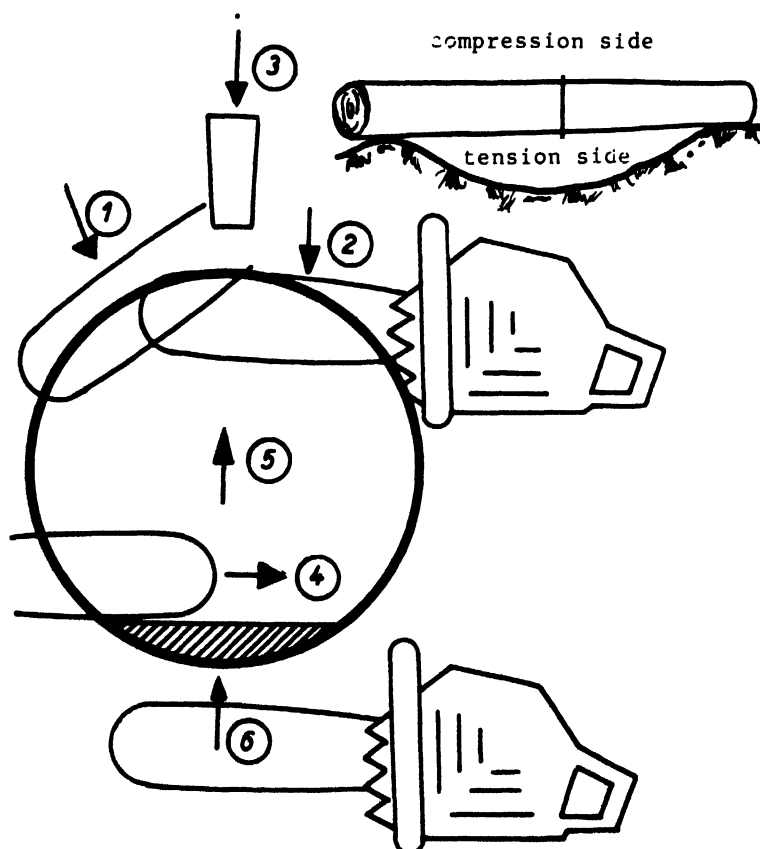
# Double crosscut (stem diameter up to twice the length of blade)



If working on slopes, cutting position is first on the valley side then on the mountain side

It is important to remember on which side the stem has a pull weight or push weight (tension or compression)

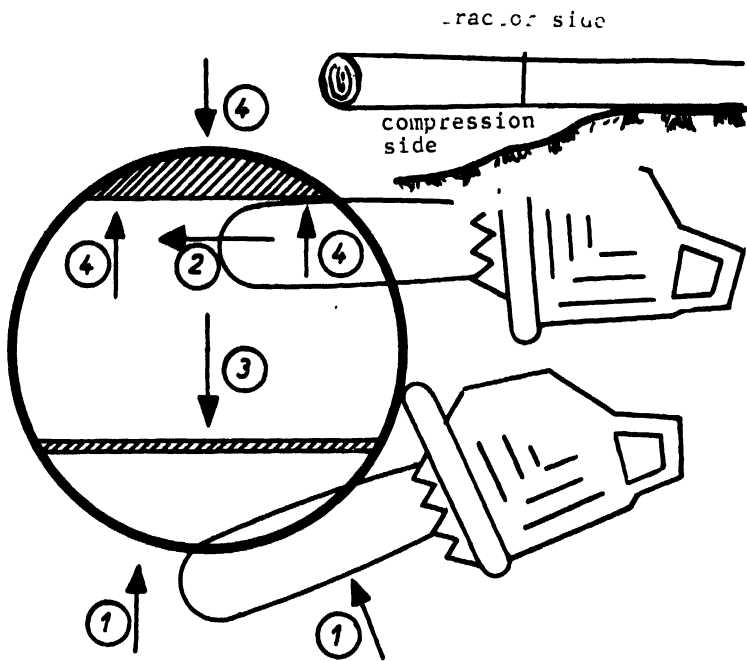
## Crosscutting suspended stems



Wedging (3) must start early enough, tension side (6) is cut from safe distance (keep escape clear)

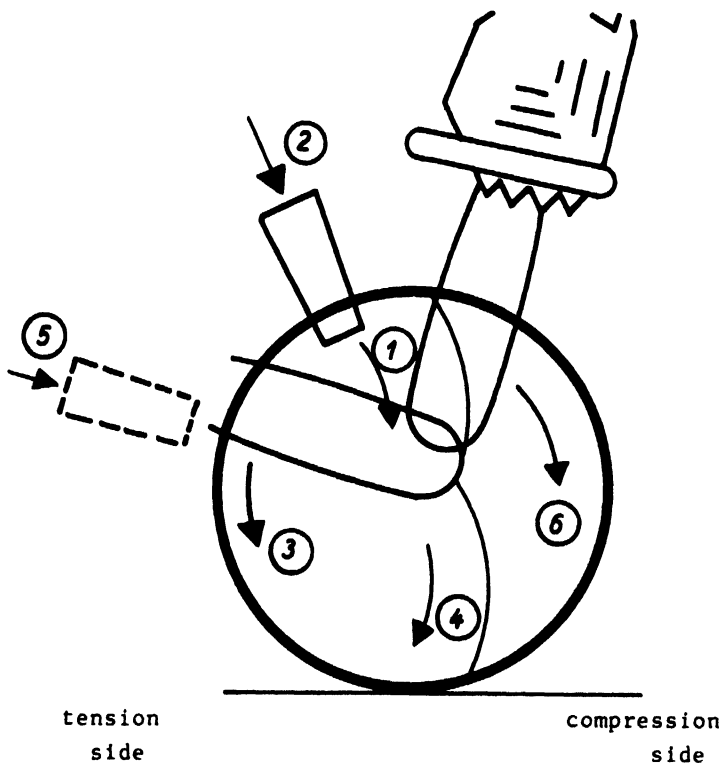
In dangerous conditions one-man saw with long handle is more appropriate

# Crosscutting overhanging stems



Thin strip (3) is left.  
"Barber's chair" may also  
be cut by axe in case  
of danger

# Crosscutting clamped stems



Cutting starts on  
compression side  
and is continued on  
tension side.  
Wedges are used

## 8. SAFETY MEASURES

Forest work is still among the most dangerous of all occupations. Many accidents can be traced to carelessness, disorganization, false economy, alcohol consumption, etc.

Employers and employees are required by law to observe special safety regulations. In case of an accident, supervisors are questioned and the possible faults investigated. Regulations provide for substantial punishment under criminal and civil law. Forest work should be carried out only by physically and mentally qualified workers. It is important not to put excessive strain on workers since fatigue and insufficient concentration increase the risk of accidents. Daily routine should be interrupted by sufficient breaks for rest and meals. Several short breaks are better than a few long ones.

The left half of the worker's body, his left hand and leg are particularly at risk because the power-saw, like other tools, is designed for right-handed workers.

Forest workers are required to observe the following safety measures:

- Only authorized personnel should have access to the worksite;
- One supervisor is necessary for each operation;
- In case of dangerous work (such as felling and skidding) at least one other worker should be within calling distance;
- Appropriate clothing, tools, equipment and machinery must be used;
- Safety distances (e.g. 1.5 times the tree length in felling operations) should be observed;
- Workers should have a sound footing;
- Machines must be turned off before checking;
- Special warning signs or guards should be placed on public transport routes when operations are carried out nearby;
- Petrol, oil or lubricants should be kept at a safe distance from open fires.

# APPENDIX A

## Piece-rate chart

for standard value table of coniferous timber felling by power-saw

### I accessibility

	A	B	C	D	E	F	Sum of values	Felling	Delimbing	Debarking	Cr. cutting
1											
2											
3											
4											

### II slope

----- %

### III diameter

----- cm

### IV log length

----- m

### V marked trees

----- %

### VI tree length

----- m

### VII total branching

----- %

### VIII branch manip.

no br. manip. ☐ bundles ☐  
cushioning ☐ heaps ☐

### IX pointing

shares ☐ simple ☐ double ☐ sum of  
points ☐ 1 side ☐ 2 sides ☐ 1 side ☐ 2 sides ☐ points

### X sap period 1/

in sap ☐ dormancy ☐  
interm. per. ☐ frozen ☐

### XI forked+dead trees under 5%

☐ 5-10% ☐ 11-20% ☐

### XII conf. admixt. under 5%

☐ 5-10% ☐ 11-20% ☐ 21-30% ☐

1/ tick off where applicable  
sum of points

### XIII allowances

allowance per oper.

total allow.  
in h/m3 2/

2/ without allowances for meals and delay due to bad weather

Case 1

Clear cut in a stand of 0.9 spruce and a mixture of 0.1 fir and larch. Estimated timber production about 300 m<sup>3</sup>, of which 20 m<sup>3</sup> are larch and fir.

Description of work conditions encountered at harvesting site:

- I. accessibility: uneven terrain throughout stand, gullies between 30 and 50 cm; no other difficulties;
- II. slope: average of several measurements 30%;
- III. diameter: accurate determination only by measurements after felling, average estimated diameter 20 cm;
- IV. log length: accurate determination only by measurements after felling and crosscutting, average estimated log length 4 m;
- V. marked trees: clear cut, therefore harvest of 100 %;
- VI. tree length: average stand height 26 m;
- VII. total branching: 60% as stand average;
- VIII. branch manipulation: heaps throughout felling area;
- IX. pointing: simple one-sided pointing of all logs;
- X. sap period: felling in sap;
- XI. forked or dead trees: none;
- XII. coniferous admixture: 20 m<sup>3</sup> of total harvesting volume of 300 m<sup>3</sup> are fir and larch; coniferous admixture is therefore about 7%.

Qualified Austrian forest workers presently earn AS 53/hour (US\$ 3.12/h).  
An additional 25% is paid for piece-rate work, i.e. AS 66.25 (US\$ 3.90).

Case 1

Piece-rate chart

for standard value table of coniferous timber felling by power-saw

I accessibility

1	A	B	C	D	E	F	Sum of values
2	a	a	b	a	a	a	
3	3	3	3	3	3	3	
4	0	0	0	0	0	0	2

II slope

22%, 26%, 42% 30 %

III diameter

20 cm

IV log length

4 m

V marked trees

100 %

VI tree length

26 m

VII total branching

60 %

VIII branch manip.

no br. manip. ☐ bundles ☐  
cushioning ☐ heaps ☒

IX pointing

shares  
points  
none ☐ simple ☐ double ☐  
1 side 1 side 2 sides  
3 13

X sap period 1/

in sap ☒ dormancy ☐  
interm. per. ☐ frozen ☐

XI forked+dead trees under 5%

☒ 5-10% ☐ 11-20% ☐

XII conf. admixt. under 5%

☐ 5-10% ☒ 11-20% ☐ 21-30% ☐

1/ tick off where applicable

sum of points

XIII allowances

allowance per oper.

Points per operation			Felling	Delimbing	Debarking	Cr. cutting
5			5			
14	10	7	14	10	7	15
129	50	559	129	50	559	248
0			0			157
34	131	10	34	131	10	
241	343		241	343		
	20			20		0
	13			13		
0	0	0	0	0	0	0
2		1	2		1	1
425	567	577	425	567	577	422
0.18	0.74	0.82	0.18	0.74	0.82	0.18

total allow.  
in h/m3 2/

1.92

2/ without allowances for meals and delay due to bad weather

cost per m<sup>3</sup>: 3.58 hours x 66.25 = 237.20 AS

Case 2

Thinning of 20% in a stand of 0.8 spruce and admixture of 0.2 fir, larch and pine. Estimated timber production about 80 m<sup>3</sup> of which about 15 m<sup>3</sup> are fir, larch and pine.

Description of work conditions encountered at harvesting site:

- I. accessibility: on two-thirds of total area gullies of between 70 and 80 cm, terrain therefore very uneven; remaining area shows uneven terrain with gullies up to about 40 cm; no other difficulties.
- II. slope: average of several measurements 24%;
- III. diameter: accurate determination only by measurements after felling, average estimated diameter 13 cm;
- IV. log length: accurate determination only by measurements after felling and crosscutting, average estimated log length 4 m;
- V. marked trees: thinning of 20%;
- VI. tree length: average of several measurements of marked trees amounts to 15 m;
- VII. total branching: average total branching of all marked trees 65%;
- VIII. branch manipulation: none;
- IX. pointing: none;
- X. sap period: felling during dormancy;
- XI. forked or dead trees: 8% of marked trees are forked or dead;
- XII. coniferous admixture: 15 m<sup>3</sup> of total harvesting volume of 80 m<sup>3</sup> are fir, larch and pine; coniferous admixture is therefore about 18%.



Piece-rate chart

for standard value table of coniferous timber felling by power-saw

I accessibility

1	A	B	C	D	E	F	Sum of values
quality	a	a	b	c	a	a	
area sh.	3	3	1	2	3	3	
values	0	0	1	4	0	0	5

II slope 18%, 22%, 32% 24 %

III diameter 13 cm

IV log length 4 m

V marked trees 20 %

VI tree length 15 m

VII total branching 65 %

VIII branch manip. no br. manip. ☒ bundles ☐  
cushioning ☐ heaps ☐

IX pointing	none	simple	double	sum of
shares	1	side	2	sides
points	3	side	2	points
	0			0

X sap period 1/ in sap ☐ dormancy ☒  
interm. per. ☐ frozen ☐

XI forked+dead trees under 5% ☐ 5-10% ☒ 11-20% ☐  
XII conf. admixt. under 5% ☐ 5-10% ☐ 11-20% ☒ 21-30% ☐

XIII allowances 1/ tick off where applicable  
sum of points  
allowance per oper.

	Felling	Delimbing	Debarking	Cr. cutting
	9			
	14	10	7	15
	175	66	610	304
				157
	15			
	63	180	19	
	246	350		
		0		5
		0		
		0	9	
	2			4
	2		3	2
	526	606	648	487
	0.49	1.09	1.66	0.34

total allow  
in h/m3 2/  
3.58

2/ without allowances for meals and delay due to bad weather

cost per m<sup>3</sup>: 3.58 hours x 66.25 = 237.20 AS



Proper delimbing is a prerequisite for efficient  
debarking, easy skidding and better selling  
opportunities (Photo: R. Heinrich)

## BASIC PRINCIPLES FOR THE SELECTION OF LOGGING EQUIPMENT

by

Leo R. Letourneau  
Director  
Forest Industries Division  
FAO Forestry Department

The selection of logging equipment which is appropriate to the situation existing in a specific tract of forest is one of the most important decisions a logging manager must take. The selection not only involves most of the capital required for the logging venture but also has a direct bearing on the profitability of the enterprise.

The manager therefore must be aware of the options for the equipment and systems available and have an understanding of their function and interrelationships. When a relatively inexperienced logging manager begins to investigate his options he runs up against a bewildering array of equipment. He may be overwhelmed by the numbers and types of a piece of equipment which has been designed to do a specific task, even though all or some may do the work in a different manner using different mechanical techniques. He should not be dismayed, for there are several methods he can use to help him select what is appropriate.

He can guess or he can buy from the most convincing salesman; he can copy from his neighbour; or he can analyse the merits of each system or piece of equipment if he is qualified. If he is not qualified he can hire the expertise to help make the choice. Before choosing a logging method he should take a rational look at the situation.

I hope that this talk will assist you in thinking about your choice or method of choosing. It is not intended to go into the mechanics of estimating production and costs but to outline some of the factors which affect productivity, and thus costs, so that you will realize what you need to know to select the correct system or equipment for your operation.

For the most part, equipment manufacturers are responsible, reliable, well-meaning people, trying to produce a machine which will do a specific job at the lowest unit cost. Many of these manufacturers will design, or modify, their equipment to suit your particular needs, and many offer services which will ensure that you get the right piece of equipment. For instance, many truck manufacturers will install components (such as the drive train) to fit your roads and loads. This may entail travel and expenses, but the results, especially if the operation is large, should pay off by ensuring dependable service and savings.

Again, many manufacturers have been in the business long enough to provide reliable and productive equipment for any job anywhere in the world. They design on the basis of experience and get continuous feedback from their dealers or sub-offices. The work which has been put into a great deal of equipment should not be ignored. Where some manufacturers fall down is in not producing impartial case studies of their equipment in actual producing operations; or if they do, they confine their studies to the existing markets of the developed countries. Such studies do not necessarily fit conditions in developing countries and do little to help or convince people such as yourselves.

Some manufacturers provide operator training and some run maintenance courses for mechanics. The size of your order may determine the cost of these services to you. In any case you can see that manufacturers generally want to provide a product to meet your needs, which in turn will benefit them in the long run. Still, someone may inadvertently recommend a usually reliable piece of equipment or a system which is not suitable for your job. Whichever method you choose to arrive at a selection (one hopes not by guessing), you must take a close look at the situation at both ends of your logging operation. This is rationalization and must not be ignored.

Loggers and managers must know where their product, the log, is going and therefore must know what equipment will produce a product to fit the needs of the buyer. Logging cannot be entirely removed from the realities of the other parts of the forest industry and, vice versa, other parts of the industry must not overlook the importance of logging, whether as a separate process or as a part of an integrated industrial complex. Too many enterprises have treated the logging phase as an appendage to something greater, to their sorrow at some future time.

The forest industry starts with the tree, whether planted or natural, and ends at the market, yet many integrated industries fail to attach much importance to the production of the basic raw material even though the log usually represents from 50 to 70% of their production costs. You, as representatives of the logging industry, realize the importance of logging and, through the selection of the appropriate systems and equipment, are taking one step toward fulfilling predetermined goals.

Now that we have put the logging sector into some perspective, we can talk about how to rationalize the choice of logging equipment.

The primary objective in selecting equipment should be an economic one, that is, to choose the one which will earn the most money, always bearing in mind and giving due consideration to the environment and to government policy. For social reasons a government may wish to proceed with a venture even though it is not financially profitable; however, the goal of economic viability through efficiency should not be forgotten. Essentially, the problem is to select an appropriate or the most appropriate logging system. Then the equipment selection problem is almost solved.

Certain preliminary steps must be taken before one can start the selection of a system. For ease of detailing the process from start to finish, the various steps can be broken down into sections, each with at least a major heading.

#### 1. THE BASIC PRELIMINARY STEPS

Prior to embarking on any venture, whether it be logging or a completely integrated industry, the potential entrepreneur must look at the following factors:

- (i) the forest resources and natural conditions;
- (ii) the market;
- (iii) the financing to marry the two with technology and action.

These three can be further broken down into numerous sub-factors, not all of which can be investigated by one type of expertise. The sub-factors will be listed and followed by a short discourse on the positive aspects and the pitfalls which may ensue if each step is not carried out, or not carried out properly.

It must be remembered that one step cannot be divorced from the others and although the factors are listed in sequence, all must be borne in mind when making an evaluation.

(a) Inventory

An inventory of the forest must be carried out and this requires special skills. In most countries, forest services are capable of doing this work. However, they may not put the correct emphasis, from your point of view, on it. For instance, many people spend a great deal of time gathering very precise volumetric detail when the most important aspect may be species - for often that is where the money lies. Similarly, defect and breakage studies must accompany an inventory which will be used as the basis for planning a forest industry. Remember, even a simple logging/sawmill unit can run to some US\$ 10 million. A modest 150 000 m3 log/saw/ply unit may require US\$ 30 million. For such production, some US\$ 5 million may be needed for the logging component alone.

An inventory complete with volume, decay, breakage and species detail may be sufficient to stop a project if it is being analysed in financial terms alone. And rightly so.

The inventory is the most important preliminary step, but this must be accompanied by a correct and detailed analysis. Again, more skills than those of just an inventory man are generally required.

The inventory results must be analysed for logging volumes; species, which must also yield details of weight (green for loading, hauling or floating), bark thickness, susceptibility to insect and fungus attack, in addition to marketability and the determination of market value. Much of this detail, such as green and dry weights and susceptibility, may already be available. However, if this is not the case, the inventory required to gather this information will be more complex.

The logger is interested in merchantable volumes per unit of area which can be used to estimate logging costs and road density, among other things. The pulp-mill man will usually want to know the total recoverable volumes down to a lower diameter limit than a sawmiller and he may want more details as to the colour of the wood and silica content.

Although planning and equipment purchases are normally made on the basis of a forest inventory, an operational cruise (enumeration) can be extremely useful, and since it must soon be made, it can be very useful to conduct at least the first year's cruise prior to selecting equipment.

Inventory crews and expertise are not always available; however, the expertise may be readily hired from numerous consulting firms, although the potential entrepreneur must know what he wants and what will be enough to suit his needs, before he can properly direct the people he hires.

In many cases FAO can provide much of the expertise needed through one or more of its service programmes. However, this assistance is normally limited to governments of Member Nations. Thus, state-run enterprises may qualify through requests made through their governments.

(b) Natural conditions

The operational efficiency of most logging equipment is heavily affected by the natural conditions and forces one finds in the forest area. Thus, such factors as terrain, soil, availability of road surfacing material and precipitation must be determined prior to choosing system and equipment.

For instance, fragile soils liable to erosion in a high rainfall area, on steep and broken terrain, may rule out the use of a skidder/tractor system and similarly soils in which compaction may be detrimental to growth of the next crop may necessitate the use of low ground-pressure equipment or cable systems.

In order to get this information further work must be carried out and another set of specialists will be required.

Terrain conditions can be obtained with reasonable accuracy from topographic maps made from aerial photographs. However, a dense tropical forest canopy normally hides minor variations such as low steep-sided hills which often become a costly embarrassment when road construction is started. For such areas, topographic maps constructed from details gathered by topographical crew (which can operate with the operational cruise crews) are much better; but this system is more expensive.

Regardless of cost, topographic maps or terrain information are usually a necessity for proper planning and for equipment selection. For instance, steep terrain may necessitate the use of a cable system.

Soil conditions and soil typing can be a relatively cheap venture, provided only mechanical qualities are required. However, if growth capabilities are also needed the costs will be much higher. Soil-bearing tests provide extremely useful information as to the amount of gravel required for a road, and from this the number of trucks, loaders and spreaders which will be required can be estimated. The need for a large amount of gravel will influence the size of the gravel and logging trucks as well as the number required.

The availability of gravel or other suitable road surfacing material (laterite, rock, coral) or the lack of it, will influence the transport mode (road, river) and shorten or lengthen skidding distances.

Similarly, a complete absence of gravel in a high-rainfall area, and thus excessive road construction/hauling costs, may force the decision to use a cable system with a minimal number of roads, provided the silvicultural system will tolerate its use. If the silvicultural prescription cannot be changed then the problem becomes social and/or environmental and subsidies may be required or the enterprise abandoned.

Soil seriously affected by rain and the churning effect of groundworking equipment can soon be in such a state that equipment cannot continue to work. Often long halts are required, resulting in lost productivity and high unit production costs due to the fixed costs of equipment and overheads. If workers are laid off, social damage results.

Another fact which is often overlooked is the effect of rain (and snow) on the productivity of workers. In some countries work ceases when rain starts. Rain causes slower work because of reduced vision and poor footing, especially in steep terrain.

(c) Environmental considerations

Precipitation and the effects of runoff, especially when forced into unnatural channels by roads and skid trails, are well known to most loggers.

High precipitation coupled with certain types of logging and road-construction equipment can prove disastrous to downstream areas and habitats. Careful planning and road layout and construction methods can often alleviate much or all of this so-called logging problem.

Rainfall data and stream flow data, along with a knowledge of downstream users, are as important for environmental reasons as for system selection and the effect on environment should have a bearing on your choice. The entrepreneur should begin to gather any additional data as soon as the plan to harvest is conceived.

Similarly, the flora and fauna must be considered, and if these are to be preserved more expertise is required. Logging disturbs the animals, although depending on its intensity they may return as logging moves on. However, some animals need an undisturbed primary forest. A major factor is to determine how logging is affecting their food source and its capacity to renew itself.

Environmental considerations may dictate that a forest be left untouched, as has happened in some countries. However, in particular circumstances government policy will prevail and logging for social reasons may be justified, in which case the logger must find the least damaging solution. In some countries certain areas are logged by balloons and helicopters for precisely this reason. Similarly, more costly road construction techniques are sometimes used to lessen the environmental impact.

The logger should ensure, or take steps to ensure, that he leaves the forest in a state in which it will produce another crop in addition to the other benefits which may be gained from it, provided that it is intended that it remain in forest, and is not being logged prior to clearance for agriculture or the flood basin of a dam.

(d) Government policy

The type and size of an operation will often be governed by government policy. In richer countries the need to harvest the forests may not be as great as in poorer countries which need the employment and revenue. Similarly, countries well endowed with forests can better afford to harvest the standing wealth than one less endowed.

In any case, most governments keep control of their forest in their hands and lay down the rules for forest use. In order to change the rules, entrepreneurs must be able to show (prove) that their proposed type of operation will be advantageous to the country as a whole. This requires knowhow and knowledge of your proposed equipment, its productivity and the environmental impact through its use.

(e) Silvicultural system

The system laid down by silviculturalists to ensure continuation of the growing capacity of a forest is one of the most important factors governing the unit volume recoverable and thus the harvesting system and type of equipment to be used.

For instance, an inventory in a tropical rain forest might indicate volumes ranging from 45 to 150 m<sup>3</sup> per hectare of sizes suitable for industry. However, the silvicultural prescription designed to ensure another crop and the presence of presently unwanted species, singly or together, may lower the loggable volume to 20 to 30 m<sup>3</sup> per hectare. These lowered volumes indicate a new situation with regard to operating costs and road spacing.

A country would have to be in dire circumstances or be lavishly endowed with forests to disregard a prescription which is designed to ensure another crop. Until the silviculturalist can find another solution or works from a better data base, the logger will have to adapt. In order to adapt he must be knowledgeable or he must hire trained personnel to help pick the equipment which will do the job economically.

(f) The industry to be supplied

Loggers make a product for use in other industries, therefore they must know their log market just as other industries must know the market for their products.

For integrated enterprises the industrial planner bases his unit on the market to be served. He sometimes misjudges the logging end, thus making the combination of machines required to produce the log input volumes uneven or mismatched, with some equipment remaining idle and some being overworked. This is particularly evident in intermediate phases such as loading and unloading where only a few units are needed relative to the other items.

For too long planners have assumed that anyone can log, simply because "even our forefathers did it with their backs and with oxen". The real situation is quite the contrary: the industrial organizer must ensure that he hires or buys the best expertise. In round figures, a log has cost more than double the amount paid for it in cash when it enters the mill because of the conversion factor, to which must be added the milling cost which is normally lower than the price of the log before conversion. The cost of the log is usually the single biggest cost factor in a mechanical wood based industry.

(g) Financing

Without the necessary funds neither the logger nor the integrated enterprise can get started. If they start under-funded and cash flows do not materialize as expected the enterprise will collapse, or someone else's money will have to be pumped in to save it. If you are lucky (or unlucky, depending on how you feel about government assistance) public monies may be fed in for social reasons.

The logger can get financing only by proving his plan, ideas and capability. In order to do this he must have the knowhow to draw up a plan, complete with equipment lists and production costs. These must be worked out to determine the feasibility of the proposal. Some enterprises or governments have the expertise to do this, but when they do not, consultant firms or individuals can be hired to do the job.

However, special knowledge of logging systems, equipment and its productivity and overall planning are a prerequisite to performing such studies. FAO, through its programmes, can provide assistance in this field, to the prefeasibility level, to member countries. It can also act as a neutral monitor for these governments when feasibility studies have been completed by third parties.



A rule not to be forgotten is not to start if you are under-funded. Thus, reasonably accurate equipment prices must be used in estimates. Similarly, equipment operating costs must be reasonably estimated, otherwise costs may be up and profits down, thus affecting the availability of operating funds.

One pitfall to avoid is that of buying the lowest priced equipment when money is in short supply, for sometimes the equipment is not suitable and you are soon back in financial trouble.

Government policy with regard to foreign exchange is an extremely important factor for some countries. In extreme cases, after the initial purchase has been financed, there are no foreign funds available when spare parts are needed. This can be disastrous.

## 2. THE LOGGING SYSTEM

There are many ways and many machines that can be used to log a tract of timber and many of these can be grouped or linked together to form a logging system. Generally each machine performs a specific function within a system. There are certain machines which do not readily match up with others to form a system, and yet in certain circumstances they may be an aid to the apparently incompatible system. Simple examples of this are a tractor cleaning out difficult corners for a cable system, or being used as a mobile tailhold for a skyline cable system, or feeding logs to a skyline system.

A system, therefore, as the word implies, is a planned method of logging, from standing tree to final delivery point of the log. Since a system implies planning, pre-planning, inventories and engineering surveys are, or should be, a part of it. This paper will confine itself to the production equipment portion of logging systems, bearing in mind that the preliminary steps enumerated earlier are a prerequisite to any system and eventually to equipment selection.

Since the groupings required to form a system are very complex we will confine ourselves to the major systems of extraction and transport, both of which form the most important equipment component of a system, and follow up with ancillary or auxiliary functions which are also extremely important but in most cases fit into any major extraction and transport system.

There are innumerable extraction systems which, if fully discussed, could fill many books. We will therefore keep to the - until recently - more standard systems which for the most part will be appropriate for indigenous tropical rain forests. However, some of these systems are also suitable for the tropical and sub-tropical plantations which are now reaching maturity and ready for logging. The latest and most highly sophisticated systems now in use in the northern temperate coniferous forests, and aerial logging, will not be discussed. Basically long-distance transport is part of a system, but since it can fit with any extraction system it will be treated separately.

### (a) Major extraction systems

Some loggers break their major systems down to the length of log or tree which is to be produced. However, we will stick to the major extraction methods. These are basically: cable (off, or partly off, the ground), tractor/skidder (often called ground skidding), semi-mechanical light equipment (such as the winch lorry of southeast Asia, farm tractors with or without forestry attachments) and manual/animal (swamp logging in some countries).

At this point it must be remembered that the extraction system cannot be divorced from the transport system and the auxiliary functions such as felling and loading. Each can or will have an effect on the extraction system.

The basic problem of the planner/investor is how to pick the system which will (a) provide logs at the lowest cost and still (b) be compatible with silvicultural and environmental needs and (c) adhere to government or company policies (employment, foreign exchange). The problem is amplified for those who have little or no experience to guide them. These three basic points, jointly or singly, will or may force a decision on the use of a certain system or method and in any case they will, or should, provide some of the answers to the handling of other criteria (unit volumes, soil considerations) which must then be brought into the selection system to form our guidelines.

Each of the systems mentioned above is affected by certain basic criteria which differentiate it from the others. The effects of some of these criteria show up on the balance sheet once the wrong system has been tested. Similarly, a selection which eliminates their bad effects or utilizes them to advantage has a positive effect on profits.

The preliminary data, gathered in the initial stage, is where the conditions and/or numbers necessary for an evaluation are obtained.

The basic criteria which will influence the choice of a system are:

- topographical conditions
- weather (precipitation, heat)
- soils
- silvicultural systems
- volume per area
- volume per log

and these are variables which must be considered when you attempt to rationalize a choice, for each system is sensitive to one or more of the criteria.

Other criteria which enter into the calculation are:

- availability of manpower
- mechanical capability of personnel
- operational capability of personnel
- present experience of personnel
- animal power, availability/experience
- accessibility/infrastructure

The latter are simple to explain. One would not normally choose the most sophisticated (and expensive) equipment if the available people are not mechanically inclined, unless for some policy reason the entrepreneur is willing to forego immediate profits until a training programme has remedied the situation. Normally in such cases one starts off with a less sophisticated system, where feasible, and works upward as experience is gained and as original equipment wears out or where special circumstances dictate, such as dwindling supply or workers. Similarly, accessibility is easily understood as a concept but can become a major problem affecting the selection of a transport system.

The major criteria defy a simple system of evaluation which will show the relative effect of each as merits or demerits in or upon each system, or between systems. In order to show this, the interlinkages and variations within criteria must all be defined and would be the subject of a book, let alone one paper. The delineation is not so severe for one piece of equipment or system, but is excessive when systems are bridged. Perhaps the best way to point out the effects of criteria would be to handle them system by system and then let the reader draw his own conclusions for his particular circumstances.

(i) Cable system(s)

There are many methods of cable logging. The primary ones may be called high-lead and skyline with innumerable variations, especially in the skyline method. This paper is too short to describe them all, but suffice it to say that there are the heavy-duty systems in use on the west coast of North America, the Philippines and Borneo, and the lighter cable systems used in swampy ground in the southern USA, as well as the numerous lighter skyline methods used predominantly in the mountainous regions of Europe and in a few developing countries in Latin America, Asia and Africa.

Topographic conditions such as steep slopes and broken terrain are not a serious factor in cable logging - let us say not as serious as in tractor logging. The major problem which such conditions impose on the systems is mostly to do with labour which must be well trained and which can be very unproductive in difficult terrain.

Cable systems have been used on slopes which vary from flat to steep. However, level ground, especially for the heavier systems, is not always the best from the cost point of view on which to use cables, unless soil conditions dictate its use. Because cable logging requires very well trained and skilled operators it should be limited, if possible, to forest areas where no other extraction system can work satisfactorily.

Rainfall and snowfall are not excessively detrimental to the systems, but the effect on the loggers can drastically reduce produce production. Rainfall and its effects on soil are negligible with regard to movement of the log, since the heavy machinery is stationary. Incorrect planning in the high-lead system can lead to serious erosion.

Similarly, excessive heat can have an effect on labour productivity, but this is common to any system.

The silvicultural system prescribed can be a limiting factor in the use of cables. If, as in many tropical forests, a diameter limit selection system is imposed, not only may the volume be lowered to the point where cable logging becomes uneconomic but logging a few trees among many standing ones without damaging or destroying the residual stand is a difficult task. Some prescription as to damage to residuals, if rigidly enforced, could preclude the use of high-lead cable logging and some skyline systems.

In some areas where the forests are rich and heavy volumes are to be removed and where regeneration is assured, the system(s) can be used effectively. Essentially, cable logging is best suited to clearing felling operations.

The size of log dictates the size of the cable system. However, since in many cases the fixed machine costs plus the fixed cost of time lost in setting up the system are very high, the size of the area to be logged (setting) and the unit volumes per unit area are critical. The critical unit volume varies with regions and experience of the logging crews. The new, larger and costly (some over US\$500 000) west coast-USA portable units have considerably reduced the moving and setting-up time, but the volume over which these items must be written off is still a factor to be reckoned with.

The following is presented to give some idea of the volumes some companies are logging with high-lead systems in southeast Asia on tropical hill forests: one operator high-leads on volumes of some 130  $\text{m}^3$  per hectare and roughly 2 000  $\text{m}^3$  per setting, while another stopped high-leading with approximately the same unit volumes but smaller total volume per setting, due to the broken terrain which reduced the area per setting. He found he could log more cheaply with tractors. At another location another operator is high-leading some 50  $\text{m}^3$  per hectare of forest on terrain which is not too steep, with an average volume in the order of 1 200  $\text{m}^3$  per setting.

One report from the early nineteen-seventies indicates that certain Philippine loggers were high-leading in stands which yielded between 80  $\text{m}^3$  to 100  $\text{m}^3$  per hectare and with average setting sizes as small as 15 hectares. Some operators use two or more systems and therefore can afford expensive operations which are necessary because of the terrain conditions, and still reach an acceptable average delivered cost.

From the above you can see that the spread is wide and it must be noted that the tropical forests of southeast Asia are the richest in the world.

The selling price of the log will determine how low a unit volume can be logged, but if you can choose a cheaper system which is capable of efficient logging in low-volume forest, your profits will be higher.

Special training is required to use the system, and experienced supervision is essential if the best techniques (tricks of the trade) are to be used effectively. Some companies trying cables in Asia have failed.

For plantations, skyline systems can be very effective and the light multi-span skylines of alpine Europe can assure longer set-ups and substantially reduce the amount of road required. On gentle, easy terrain, however, a skidder/crawler system is likely to prove cheaper. For single-span skylines the shape of the slopes to be logged is very important; without the deflection obtained by a concave shape the system cannot be used, which indicates the need for accurate topographical maps.

The best advice one can give on cable logging is to bring in experienced loggers and forest engineers as assessors. They can be obtained from the Philippines, where high-lead logging in tropical forests has been practised for a long time, and from temperate countries for logging plantations.

(ii) Tractor/skidder systems

A term often applied to this system is ground skidding. The fact that the skidding machine runs over the ground, dragging one end of the logs, gives a picture of the effects of some of the major criteria on the system.

Tractors (crawler tractors) can be used alone or they can be used with another machine, the articulated four-wheel-drive skidder. These two machines make an effective combination and in most cases the skidder cannot be used without the assistance of a crawler tractor. The ratio of crawlers to skidders generally varies with the terrain and log size; these vary from 1:1 to 1:3 as a rule. A 1:2-ratio logging unit can now cost in the order of US\$ 300 000 or even more.

Both machines (and therefore the system) are very sensitive to terrain conditions. The crawler is limited to slopes of 40% to 60% but the upper limit should not be considered a norm, and the adverse grades must be limited to some 15% to 20% and only for short distances which do not occur too frequently. I have seen large crawlers skidding logs up steeply sloping skid trails in the order of 40%, but production was low.

The skidder is normally effective only on slopes up to 30% or 40% with the upper limit being considered only occasionally. This machine which is intended for fast hauling is very sensitive to adverse grades since the lost time (or smaller load) involved in trying to skid or winch a turn up the adverse grades defeats the purpose of the machine (high productivity through its speed); thus broken terrain becomes an important consideration. Similarly the advantage to be gained by fast skidding over long distances is lost in adverse terrain and a consequence is that more high-class truck roads will be required. The introduction of the skidder to the ground skidding system did lower the amount of truck road required per area logged. These machine limits have been presented here to indicate the effect of terrain on the ground-skidding system.

Soil types and the effect of water on them is equally important to efficient skidder use. Good, apparently firm soils sometimes become quagmires when wet. In areas of high precipitation a careful look must be taken at both these criteria and their possible combination. Extremely wet conditions can either slow production per day or can stop operations over days. Limiting the number of days a machine or machines in combination work raises the fixed charges and machine inventory carrying costs, sometimes to the point of making the operation unprofitable.

A new skidding machine has recently come on the market which may help overcome the detrimental effects of water on skid ways and improve the adverse skidding capability of skidders while retaining the advantage of skidder speed, thus enhancing the chances of using a ground skidding system. The machine is now in use in some places in the tropics. Without going into great detail: the machine is a high-speed tracked vehicle capable of operating in muddy conditions and on slopes to 35%. It has an added advantage in that it exerts relatively low unit pressure on the ground.

Conventional ground skidding does bare a lot of soil and can lead to serious erosion problems but careful layout and training of operators can lessen this problem.

The effect of the silvicultural prescription on this system is not as serious as for the high-lead cable system since skidders can manoeuvre among standing trees. However, the use of machines which are too cumbersome, along with improper supervision, can play havoc with the residual stand. These problems can be overcome with careful planning and supervision.

Crawler/skidder logging can be carried out profitably often at low unit volumes, but the high value of some tropical trees is a great help. There are virgin forests now being logged from which only 15 m<sup>3</sup> per hectare are being harvested. Some rich forests of southeast Asia yield over 100 m<sup>3</sup> per hectare. Generally the minimum volumes which can be logged or the point at which one takes another look at all the other factors to see if they will alleviate the possible high costs, is in the order of 30 m<sup>3</sup> per hectare.

The size of tree and/or log dictates which size of tractors/skidders you should choose, but not necessarily the system, for crawlers and skidders come in many sizes.

The ground skidding system has been in use around the world for a long time and the use of crawler tractors is common in other fields, therefore the chances are quite good that in most countries there are expert crawler tractor operators. They may, however, have to change their outlook and methods to skid logs effectively. Skidder operators will be more rare and require special training even if they have previously operated crawlers.

#### (iii) Semi-mechanical/light mechanical

The heading for this section may appear to be wrong; however, it is intended to convey the idea that there are many pieces of equipment other than highly specialized and costly units which function very well under specific circumstances. These systems have a distinct advantage in that the components are not too sophisticated, nor are they usually too expensive, plus the fact that they require more labour input which often meets a critical social need.

Normally these systems are not adequate to supply logs for large operations since their relatively low productivity makes the logistics problem enormous. They can however often be an arm of a large operation, producing in special areas and at a low cost.

Two systems which come to mind and are worth discussing are the winch lorry system of southeast Asia and the farm tractor ground skidding adaptation.

The winch lorry system has been in use for some 35 years and has performed very effectively in easier terrain. However, with the move to the mountains which was required as the forests receded, the system adapted and went along. Originally a tractor was used only to build crude roads, but in steep and rugged terrain the tractor became the prime mover, bringing the log to the winch lorry at the road. The ratio of winch lorries to tractors is in the range of from 3 to 7:1. The system is still in use in Malaysia and Indonesia. It is believed that the Philippine version called the Bataan logger is still in use but to a limited extent.

Terrain conditions are a limiting factor with normal winch lorry roads being limited to 30% grades, but I have seen them hauling down slopes of 50%. In one case the logger used logs as a drogue.

Adverse grades naturally also slow the lorry down but since most winch lorry roads are crude the normal speed is slow. Adverse grades of 35% have been measured.

Soil and the effect of water on it is important, but the six-wheel-drive feature permits the operation to start up soon after the rains stop. Production is definitely a lot lower during the monsoon months. The machines are usually operated on contract or through a contractual system and since they are relatively cheap, down time is not as important as for expensive machinery being operated by daily paid workers.

The system can function on very low unit volumes, as low as 8 m<sup>3</sup> per hectare and has been particularly effective in relogging, as market trends for species change. With a prebuilt rudimentary road network I have seen an operator logging an area (third time over) and bringing out less than 5 m<sup>3</sup> per hectare.

The system is unsophisticated and drivers and crew soon learn to repair all but the engine of the lorry; the tractor being as in any other system. It is labour-intensive and production costs are usually lower than the major systems. As old machines wear out and higher-priced trucks are needed, the system may lose a bit of its low price advantage; however, costs of other equipment are probably accelerating at the same rate. The system works very well with medium-sized to large logs and is used very effectively in some plantations of south Australia.

Farm tractors adapted for skidding form another system which fills a need for low-cost equipment and a high labour input. Manufacturers have made many accessories such as winches and towers (to form a cable unit) to fit farm tractors and they have become quite common in the United Kingdom and parts of Europe. They are limited to small trees and do very well in logging plantations on moderate slopes, to, say, 30%. Essentially the same limitations apply for these as for the winch lorry.

#### (iv) Manual/animal labour

This section does not readily fit into the theme of this paper. However, it must be mentioned because it could be one of the choices available to you, and it may remind you that you don't always have to buy motor-driven equipment to move logs from the stump to the carrier or dump.

An excellent example of this is the kuda-kuda system of Borneo, where it is used to harvest the freshwater swamp forests. Until recently the tree was even felled by handsaws and axes. The sole concession to power other than human is a miniature railroad with skeleton cars pulled by a small diesel locomotive, formerly used in a mine.

Many push/pull, slide/roll logging operations still exist and produce logs more cheaply than we normally do with our high geared machinery. Manufacturers make sleds, chutes and pans pulled by radio-controlled winches and the like over and above axes, wedges, levers and jacks.

Animal pulling power has only recently left some of the temperate areas. Today Malawi is in the process of training oxen for log skidding. Elephants are still used in Asia. The manual systems are not dead yet, and you may find areas where they fit the bill. The main point in non-use of manual logging is that as people get more sophisticated they want change, and everyone prefers work which is less physically demanding. The logistics of supplying a large industrial complex using these systems would be an enormous headache.

Now that we have reviewed the basic, but not all, extraction systems, you are probably as unsure about what system to use as you were at the start. You really should not be, because the basic limiting criteria have been pointed out. With a knowledge of your forest and its environs you should at least be able to assess probably the most suitable system. Individual pieces of equipment within a system are essentially only a matter of numbers, sizes and configurations and will be covered in a general way later on in this paper.

One thing which should be evident from the above is that ground and cable systems are not readily comparable because they are different techniques designed to operate under different conditions. Therefore one cannot say which is the best. Loggers under actual operating conditions soon determine which is the best as far as they are concerned, but they may be biased by their earlier training, and governed by the particular circumstances or physical criteria of their particular forest or the original forest they started in. One thing is certain - training followed by experience is the surest way to find the right system for any logging operation.

(b) Major transport modes

The other major phase of any logging system is transport. Each of the transport systems listed below can be used with any of the extraction systems enumerated earlier. However, we must choose the appropriate one. Sometimes we have no choice but one, and its use is obvious.

Basically there are three ways to move logs over long distances, and these are: by truck, by rail, and by water. The basic criteria for extraction methods apply also to transport, but as is evident, accessibility and availability of infrastructure and waterways become a key issue in transport.

One thinks twice before going in to log an area which is very remote. If there are no public or private roads (or a railroad) within economic hauling distance from the forest then the extra cost of construction of a long access road often deters the investor. The presence of good, usable public roads often changes the picture - for instance, logs are being hauled for from 3 000 to 4 000 km in Brazil, although they are of selected species and at back-haul rates. Wood-hungry industries in parts of Asia haul logs for from 160 to 500 km.

Basic data collection therefore must include information on public roads, railways and waterways. Where coastal and seagoing log movement are contemplated information is required on port capabilities, rules, shipping and handling rates.



The major basic method of transport has now become trucking, for accessible forests have almost completely disappeared from the vicinity of coasts and rivers. Occasionally all three methods will be used to move the same log. Some logs are trucked to rail, railed to water and floated to mills. Generally, however, two methods are the norm for a combined system. In most parts of the world where water transport is used, the logs must first be trucked. Basic data yield the information required to tell what other method can be used to lower costs. Certain parts of Amazonia are still producing large quantities of logs without the use of trucks.

Railroads are a cheap method of moving logs, but the logging railroad has almost become extinct because of its inflexibility with regard to terrain, and public railroad haulage can be cost-effective.

The transportation problem with most forests is that they are no longer accessible to a waterway which affords the cheapest kind of transport. Therefore, logs must be trucked. Once they are loaded it is a simple matter to hook on to a public road and deliver direct from the forest to the mill yard (so-called door-to-door delivery) provided the distance is not excessive. Such movement is rapid: logged today and at the mill today or tomorrow. Tacking on another mode involves extra handling and delays and the manager often loses some control over his logs for a period.

Of the three modes, especially for long-distance movement, it can be said that the cost per unit of log is in the ratio of approximately 1, 1.5 - 2.5 and 3.5 - 5 for water, rail and truck respectively, naturally with great variations for efficiency and ratio of fixed time (loading, unloading, terminal costs) to hauling time which is essentially a function of dead time to haul time plus load factors affected by regulations and road conditions, stowage and service. Hauling costs are sometimes higher on inefficient railways than by truck. Road, spur and loading facility costs are extra in all cases.

The various factors which affect costs are time, distance, terrain and weight (volume). One can readily see the interplay between these items. For instance, a road with poor alignment and a low carrying capacity due to difficult terrain conditions and lack of surfacing material will require low speeds (time) and less will be carried per trip (weight/volume).

Similarly, on a winding serpentine river, barges will travel more slowly and costs will be higher than on a straight river.

However, these factors need not affect each transport mode to the same degree provided one knows the relationships of each. For instance, on a twisting road or river you may be able to increase the load size, partially lowering the increased unit costs due to time.

If one were to calculate the unit cost per  $m^3$  of transport for the three modes over varying distances one could plot a graph of these which would look somewhat similar to the one shown in Figure 1. One must remember that there can be great variations.

The truck is much more versatile than rail in difficult terrain conditions, but truck hauling is very sensitive to soils and water, and so to the availability of surfacing material for all-weather haulage. More gravel means more expensive roads. Thus to hauling costs the cost of forest roads and their maintenance must be added. In most cases, however, roads are necessary for a first move.

Trucks come in many sizes and configurations. The system is so prevalent that many firms manufacture trucks and trailers just for logging. These are generally in the heavy-duty range and cost of one unit can run over US\$ 100 000. Trucks in the medium- and light-duty range are usually assembly-line units with perhaps some special features such as modified frames, heavier suspensions and axles.

A careful look must be taken at the units to be purchased for trucking, once it is decided trucking is necessary and/or desirable. The size of the operations and the operational periods and shifts are basic to any calculation; however, load size, affected by the green weight of logs (and bark), and load limits on public (and some private) roads are equally important in the final selection. Some trucks, without load, weigh as much as permissible gross vehicle weights on the lower-standard roads which are often found near forest areas. Some manufacturers use lightweight materials to increase the payload. Furthermore, trailers can increase the payload, but these must be carefully considered before being adopted.

The driving capability of the crew will often govern the accessories (automatic, power shift, and power steering) and size since huge trucks are difficult for some inexperienced personnel to manoeuvre. Similarly, low forest-road standards may indicate the need for front-wheel drive and load limits are usually higher for more axles.

The loading and unloading methods can also be critical. A small operation cannot always afford to employ or buy a fast mechanical loader, therefore loading can take up to four or five hours. It is rather pointless and costly to have a huge expensive truck standing around waiting to be loaded. Another example is the pole trailer normally loaded for the return trip, which cannot be loaded or unloaded for lack of a sufficiently strong loader. In many parts of the developing world logs are loaded manually or semi-manually, or at least without the benefit of separate special loaders. Whatever the system, the truck should be bought to fit it.

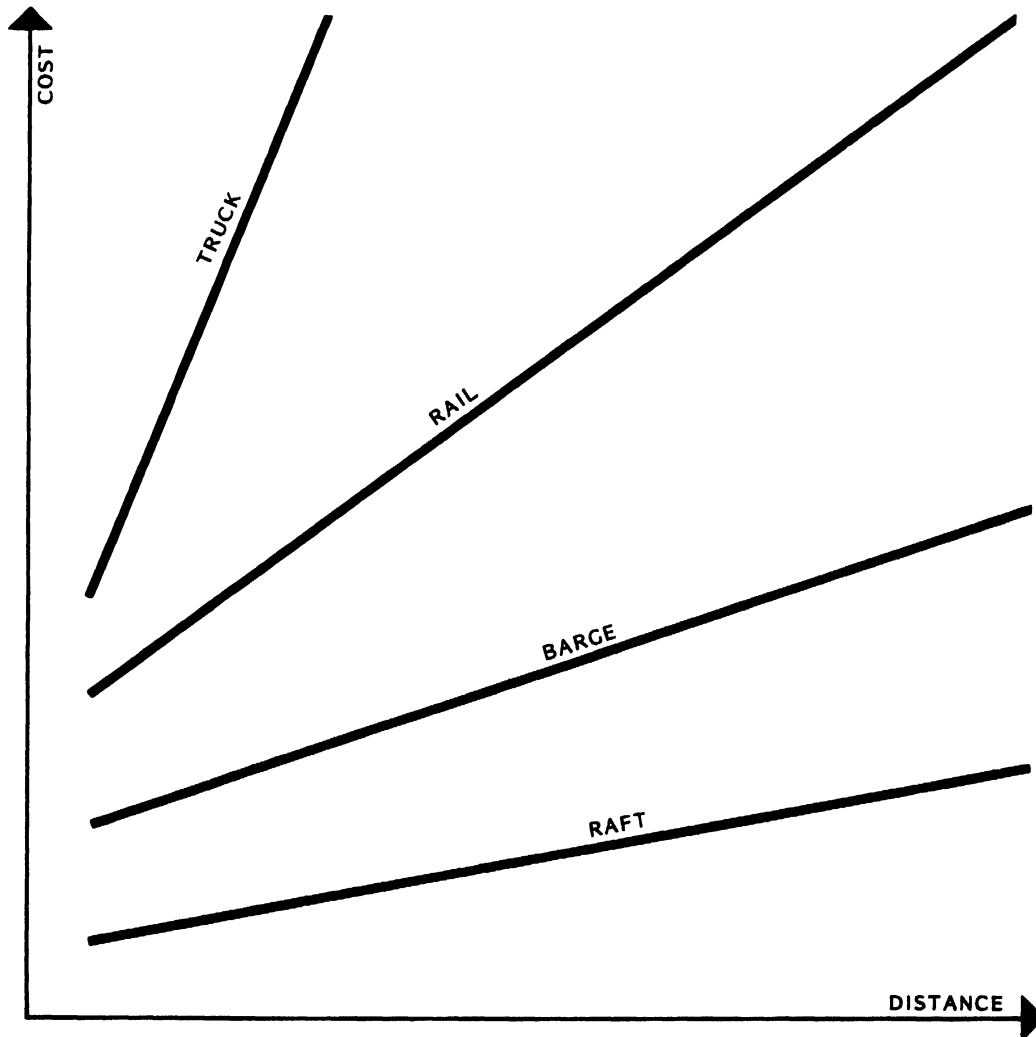
Truck hauling is often the most expensive phase of logging. Thus it is only sensible to take special care in choosing trucks and their configuration. One should remember that expertise is available, not only for the initial selection but also for the effective operation of hauling. Some companies employ full-time transport superintendents. As stated earlier most truck manufacturers will have the expertise to supply the truck to do your job, but remember you must know your requirements and have the basic data at hand.

You must know the terrain to determine the type of road you will build; sharp curves and steep grades will require certain specific equipment including trailers. The size of log required by industry and the size of your timber may require special features capable of handling, say, long logs, and here the size of truck and the extraction equipment must be well matched for the best overall performance.

Highway hauls require that you know all the regulations, those pertaining not only to speed and gross weights but also to size, such as overall length, width and height. Quite often you will find antiquated rules which no longer fit the situation. By presenting a well outlined and calculated case you may be able to assist the authorities in updating their regulations or get special hauling permits that will save you money.

Above a certain distance, hauling by rail is usually cheaper than by truck; however, in many cases the rail haul involves a truck haul at both ends, therefore these added costs, which include rehandling, must be taken into consideration.

Figure 1 - LOG TRANSPORT COST RELATIONSHIPS



In some countries rail hauling on public systems is not as efficient as truck hauling, and private railroads into the forest area are seldom found because of the difficult terrain in the forests. Because of this it is doubtful that anyone still extracts directly to a railroad. (An exception being the mini-railways of the swamp forests of southeast Asia, which are the only ground-haul methods suitable and which usually haul only short distances to the nearest river).

With the increased and probably continually increasing cost of fuel it is possible that some companies will consider putting in rail for their long hauls. Remote areas will probably be best served by rail which is put in for another purpose, say for mining. In all public rail hauls the logger is at the mercy of the railroad and generally railroaders have not given much time or effort to help the logger's transport problems. Railroaders often claim the logger is inconsistent in his delivery. Perhaps his inconsistency is the logger's own fault or perhaps he is inconsistent as a result of the government's forest licensing policy.

The rate structure on public railroads is usually very complex. Railways play a prominent part in the overall economic policy of some countries and often these policies are reflected in the rates for certain goods or commodities. Of course, the same can apply to internal water transport, and to some extent trucking on public roads, where rates are applied to meet a specific need or to encourage/discourage certain activities, often as a market regulatory tool. Before investing in equipment, a logger who must rely on rail for his long haul should ensure that he has a long-term agreement with procedures laid down on how to handle any rate alterations.

Rail transport requires special expertise if one is to operate a private road. On public roads the numbers can readily be obtained but during preliminary discussions one must ask all the questions. Railway people tend to assume that you know as much as they do. Some unmentioned items can be costly. Are the public railways willing to put into service special cars (wagons) which will handle logs most effectively? Often they will not. One skeleton car can cost more than US\$ 20 000 and cars may stand idle for a good part of the time. In addition dead heading charges may apply for the empty return haul.

Public railways (like public roads) have set load limits which must be carefully looked into when you are calculating hauling costs or rate structures. Green weights and bark can make a haul expensive, especially if the wrong cars are used and load configuration (pyramid) is regulated.

Until recently at least, road transport for commodities other than logs has cut into the railway business so badly that many railways have become unprofitable. However, where rail service is available, using it should be considered, especially for long hauls. Similarly, if a logger must build private roads over great distances served by a railroad, the rail haul will usually be preferable unless service is too unreliable.

Water transport has always been the most economical method of moving logs, but the water system is not always available in the forest and trucking is then resorted to.

Ocean transport is a specialized business and implies moving logs out for manufacture in another country, therefore it will not be covered here. However, one should mention that Indonesia, the Philippines and Brazil, for instance, have vast distances which can be covered within their territorial waters. A look into these would be the subject of a complete transport study.

Traditional water transport normally entails floating the logs on rivers in controlled groups without use of equipment or towing log rafts and/or bundles and barges with tugs. The former is gradually disappearing along with the river drives of the northern coniferous forests. Rafting and barging are still quite common though mostly restricted to countries well endowed with rivers and/or a sea. In Indonesia vast amounts of logs move down the rivers to tidewater ocean shipping points or mills. Similarly, most logs in Amazonian Brazil move on the Amazon or its tributaries.

For obvious reasons a logger must know the green weights of his timbers and the conditions of readily available rivers or the sea. Remote forest areas can appear accessible until one observes the river flows during the often prolonged dry season. Fast river flows can preclude towing upstream or raise costs considerably.

Tugs used for towing or pushing must be especially designed for this particular application. Although one sees "any old boat" towing log rafts and barges in many countries, they are not often the most efficient. The main advantage is that they are already owned or that the owner will charter out at low rates.

Tugs used for moving logs come in all sizes, and power sources range from less than 100 hp to big barge puller/pushers of over 1 500 hp, depending on the application. Costs can run over US\$ 1 million. Initial capital outlay for a barge/tug system can be a sizeable amount. For instance a tug (towing/pushing) and two 2 000-ton-capacity barges can cost over US\$ 1.5 million, depending on the country of construction. When log barging is being considered a careful look must be taken at the stowage factor. A between-decks or welled barge will not usually handle as many logs in volume as, say, a flat-decked deck-loaded scow, and loading is simpler on an open deck.

Thus it can be seen that it is important to have a tug with the correct features, one of which is the power source and the correct barge. Regardless of the high figures quoted, if you have a floatable/navigable river it is essential that you investigate its use. But while you are investigating, be sure to check on boat crew staffing and manning regulations. The rules sometimes force an operator into more capital (and operating) outlay than he envisaged. For coastal or deep-sea shipping, the operator is forced to use water but sometimes he can negotiate or force lower rates.

In areas with good rivers and coastal waters along with a forest which supplies floater logs, simple rafting systems are most often the answer. The surest and fastest method is to tow the flat or bundled rafts of logs and, again, specially designed tow boats are the most efficient.

Wherever trucks are used forest roads form an important part of the transport system and equipment must be available for their construction and maintenance. In general it can be said that the factors which affect cost of extraction by crawler will have a similar effect on road subgrade construction equipment, where crawlers predominate. A tendency which has emerged of late is the use of power shovels and back-hoes for subgrade construction in some temperate countries. This method could well be the answer to some problematic soils in the tropics and could also help to alleviate environmental problems associated with or caused by the crawler method of construction.

Surfacing and grading equipment are basically standard. However, the size of gravel trucks may cause a minor selection problem in order to balance out the loading. If gravel is applied only lightly and over a short period of time, the trucks might stand idle unless they can be turned to other uses. In such circumstances an operator might do better to hire (or contract) his trucks and loader for the requisite period, if he can.

Road construction is a specialized task requiring a lot of supervision; so much so that most large well-run companies employ a road foreman.

### 3. ANCILLARY PRODUCTION FUNCTIONS

Although these items have been listed in this paper as being subordinate they are by no means insignificant, and if not properly carried out can disrupt an operation to the point where production is drastically lowered or costs are raised unnecessarily.

The same basic criteria affect these functions as for the major phases. We can discuss these in the order in which they normally take place in an operation.

#### (a) Felling and crosscutting

Today most of the world's industrial timber is felled by means of chain (power) saws. These are simple, relatively cheap, little machines which are easily serviced by the operator or owner. However, they are a high production machine and have increased a worker's output many times over the manual axe/saw methods.

Because they are so fast they are a potential danger to the worker, so in addition to selecting the correct saw (horsepower, blade length and safety features) it is incumbent on the operator to see that fellers are given careful training in their use and proper felling techniques.

Safety is not the only reason for training fellers. Good felling techniques can make extraction easier and reduce extraction cycle time. Good techniques can also reduce breakage. It does not take many broken trees of a valuable species to make you wish your fellers were trained!

Hand felling and sawing is still used in some countries, especially for fuelwood and small-tree felling. Axes are wasteful and this becomes a serious matter in wood-deficient areas.

Productivity in felling is also affected by terrain and weather; and the size of a tree may cause a feller to work longer on it (although if the tree is tall, he will make up in volume).

One could not begin to name all the brands of chainsaws on the market, but it is sufficient to say that the market is big and competition among manufacturers ensures that they put out a good product. Most have a large research and development staff engaged on improving their products.

Finally, associated with felling are items such as clothing (helmets), hand tools, files, repair tools and jacks, to name a few. These may seem minor but they are essential.

#### (b) Debarking

Debarking is still done manually in the forest in many developing countries where logs are generally debarked before they enter the mill or are exported. A logger must decide whether to do this in the field, manually, or let the miller do it either manually or mechanically at the mill. The logger's main concern is labour availability and whether or not the weight of the bark will affect the load size which he can haul; and, of course, he must be reimbursed for his work. Tools are simple and readily available.

(c) Loading

Loading normally entails loading logs on to a truck at the forest landing but may also be required for rail and barge hauls. Loading can be carried out at the stump for pulpwood. There is not normally the same urgency to mesh rail and barge loading with extraction and hauling, since these two means of transport are normally fed from a stockpile as and when the wagons and barges are ready. When barges and wagons are available, however, the loading process must be fast and efficient.

In truck hauling the most difficult piece of equipment to fit into the overall scheme is usually the loader. This is especially so in small operations where the logs are big, because the large piece of equipment needed to load big logs is overproductive and would be under-utilized. Many small operators do without, and devise makeshift systems or use self-loading trucks, all of which are usually slow compared with mechanized loaders, and tie up the truck for long periods, so that expensive powerful trucks also become redundant. Conversely, underproductive loaders hold up trucks and so raise hauling costs.

Nearly all loaders are now mobile. Boom-loading in cable operations is still practised but its use is declining. Mobile loaders can be said to be front-end loaders, mounted on wheels (rubber) or tracks; heel-boom hydraulic loaders also on wheels or tracks; and the hydraulic knuckle boom grapples used for loading smaller trees or logs and pulpwood. Knuckle boom grapples can be mounted on anything from a hauling truck to a farm tractor.

Loaders have varying degrees of sophistication. Large-log loaders are costly. Big heel-boom hydraulic loaders can cost more than US\$ 300 000, so they must be productive. To be productive they must be where the logs are and usually to be where the logs are they must be mobile.

Decision on the size of loader depends on the log size, which has been decided in the extraction and/or transport phase or by mill requirements. The decision on whether to use wheel- or track-mounted machines depends on how mobile the machine must be, which is dependent on the distance to be travelled between loading points and on the soil and water conditions. For some special loaders adaptation to rubber-wheeled mount can raise the cost considerably, even 40% above the cost of a track-mounted model. Front-end loaders mounted on rubber cannot always function on wet, soft landings - they soon slip and slide and bog down. Track-mounted machines move more slowly and their weight is better distributed, so they do not churn up the landing so much and are not so vulnerable to soil and rain conditions.

Thus, for certain soil conditions a track-mounted (rubber if the road surface is wide enough) heel-boom loader, loading from logs piled (windrowed) beside the road, is sometimes the best solution. This, of course, entails being able to place the extracted logs in windrows. Clear-felled forests logged with a portable skyline system are well suited to this loading unit. Ground skidding in a partial harvesting system could possibly also use this method and so eliminate the need for clearing large areas for landings and consequent extreme disturbance and compaction of the soil.

On some big operations where loading time is a significant part of a truck's total available time, some operators preload trailers so that the truck (tractor) which is the expensive part of the unit is moving more or less continuously. The preloading must be much faster than normal loading in order to make the extra investment pay. Preloading also requires more space and better landings than those required for direct loading.

Rail and barge loading usually require special loading points and the proper loading equipment is dependent on the facilities provided. A key factor is the ability to manoeuvre the logs so that they take the least space in the barge or on the wagon. Some railway companies charge by the wagon with weight limits, and, naturally, according to distance, so a logger must ensure that he loads the maximum allowable. The same principle applies to barges.

Because loading is such a critical function, spare capacity in marginal situations should be allowed for. This could entail the cost of another machine idle, possibly for most of the time. One solution is to try to order log unloading and gravel loading equipment which can be brought into play as required.

(d) Unloading

As for loading, the object is to get the truck back on the road as fast as possible. Often the mill takes over this function and the logger loses control of his truck. If the mill employees are not conscientious, this can be costly.

Logs are unloaded by a myriad of methods and systems, and a logger has to find the cheapest method which will also ensure that his truck is not delayed unduly. Essentially the same mechanical equipment used for loading is available but the front-end rubber-mounted loader appears to be the favourite. One must remember that log yards are usually surfaced and/or compacted and soil conditions do not affect this operation to the same extent as in loading in the forest.

An integrated operation can buy unloading equipment which will unload trucks, sort the logs for size and species, stockpile them and feed the mill. Thus the cost of the machine to the logging operation can be minimal. Big yard machines, which can often lift a whole load, are costly and one capable of lifting 20 tons costs in the order of US\$ 240 000.

Loggers delivering to water can employ A-frame unloaders which are cheap and efficient, provided the truck is suited, but sinks, which are common in tropical forests, may prevent this. Some operators use A-frames to parbuckle their logs on to the ground, get the truck back on the road and move the deposited logs with a small front-end loader.

(e) Overhead equipment

This heading covers all the non-producing items, although they are listed with the production functions and are so important that they are included here. The numbers and pieces of this equipment are large and their prices are usually smaller than production items; however, no operation can function without some or all of them. They form a part of any system.



For instance, an operation cannot be supervised properly without a supervisor and he must have transport. Similarly, the crews must get to and from the job. The state of the roads and the job to be done dictate the type of truck required. An aspect of this is four-wheel drive versus two-wheel drive.

On scattered operations and long truck hauls a radio dispatch system can pay for itself in no time. A mobile workshop will reduce machine down-time on any operation.

Just as you must know that the equipment suppliers provide good maintenance and spare parts service, so you must have a good repair depot. Shop equipment is essential and can amount to a considerable sum when you add up the cost of all the bits and pieces. There must be a stock of the essential, most often needed, spare parts.

And since there has to be cost control on the operation and on each piece of equipment and its major components (tyres, wire rope), you need an office and the equipment to go with it, such as power (plant), telephone, and office equipment. Housing and other such infrastructure can add up to a lot of money.

#### 4. INDIVIDUAL ITEMS

Once a choice has been made as to which logging system to use the equipment choice has almost been made. The only problem confronting the operator now is which individual machine fits his particular terrain, weather and forest conditions. In other words, if he has chosen a crawler/skidder combination he must determine the ratio of one to the other and the size or pulling power of each. The previous section has covered much of what could be said here but as mentioned earlier one cannot divorce one part from another in a good operation and it is just as difficult in a short paper.

Skidders generally come in three sizes within narrow limits and crawler tractors suitable for logging in about five. The selection of specific machines entails a productivity analysis based on drawbar pull and relevant speed of each machine as given by the manufacturers, and the load you expect to pull. It will be obvious in some cases that certain machines are not suitable; for instance a 75-hp tractor would not be much use in logging large tropical trees whereas a 300-hp tractor would be out of place in a pulpwood stand. It becomes more difficult to choose when tractors are in or near the same power range. In tropical forests some loggers maintain that a 140-hp tractor will do the job while others claim they need a 180- to 200-hp machine. Different soil and terrain conditions plus the length of log, plus the philosophy of logging, high speed or low speed, are generally the critical factors.

In the case of cable systems the analysis is based on cycle time or turn time, related to productivity as in ground skidding methods. In cable logging, non-productive time such as changing roads and settings must be included in productivity/unit cost calculations.

In your operations, however, you will be in one forest, therefore you can make direct comparison between machines manufactured by the same company, since the forest condition inputs will be the same. Productivity is not enough- this must be merged with machine operating cost to give a unit cost. When you are estimating, the lowest unit cost machine should be the winner, but if you overwork the smaller machines their down time might be higher than you put into the estimates or they might wear out faster than you allowed for; therefore, marginal unit cost differences can be misleading at times.

Comparison of two machines of the same approximate size and power brings a different input into a calculation: reliability, and this generally can be found out only by experience and comparison with other operators.

Comparison of two different machines designed to do the same job is also a problem if you have no operating experience behind you. You can only take the word or advice of the dealer or try to find research and study papers (especially on new units), but getting around and talking to other operators and owners is one of the better methods. If an operator continues to use a certain type of machine and is still in business he must be satisfied with his equipment. A word of caution: some people buy on price alone because of their particular financial circumstances and they do not always buy the most suitable equipment. Similarly their operating philosophy may be different from yours, i.e. high speed-low speed, longer write-off periods, and the like.

A similar process can be carried out to determine the ratio of skidders to crawlers, once the basic size selection has been made. For this system it can be said that crawlers are slower than skidders, therefore the crawler should log the nearer areas and the skidders the farther. You can calculate the distance at which the productivity of the two machines is approximately equal.

When it comes to size and configuration of trucks and extraction equipment, the size or length of log becomes very important in the selection process, more so than terrain and road conditions and other restrictions. For instance, a peeler log is usually of much higher value than a sawlog and usually rarer in the forest. Logs for plywood, and for sawing for that matter, must be cut to a specific length, with trim, to meet mill specifications. It is difficult to train the feller/bucker to buck (crosscut) his logs to the correct length and still get the most value out of a high-quality tree. Sometimes the lie of the tree prevents bucking for quality. In order to overcome this, some operators extract tree lengths and even haul tree lengths to the mill, so that trees can be crosscut under close supervision. You can see what effect this factor has on your choice of size and configuration. Perhaps you need the 300-hp tractor and perhaps you need a pole type of trailer truck with extendible reach (pole).

Nothing beats actual productivity and cost figures. Every new operator should, if his operation is large enough, hire both a cost accountant and a machine superintendent. These two should set up a cost accounting system, complete with individual machine costing. The foremen should be trained to understand phase costs and be able to pinpoint what is raising costs. Organized in this way you should have a clear picture before your old equipment wears out, and before it is time to replace it, possibly with something else. A problem in many cases is the ability to keep the key men; too often the incentive is not there and they leave for other work. Salaries form a vital part of any economic machine calculation. If a man is doing his job and worth it, pay him. Similarly, younger men should be trained so that the enterprise has continuity.

Productivity and operating cost estimates must also be made for other systems.

Imagine working your way through each machine. You will find that you need a lot of data: to name a few not yet mentioned: fuel, lubricants, tyres, spare parts (the amount to be used and the cost of each, labour rates and fringe benefits, depreciation periods, insurance, interest, resale value, and so on.

A new venture in a developing country should not try untested, undeveloped systems or equipment unless it has no other choice. And it should also be pointed out that what works in a developed country, probably in temperate forests with different criteria from those mentioned in Section 2, may not work in your case. Too many factors are involved to pick more or less blindly from a large assortment and risk having your venture fail.

Mechanized logging has been going on in the temperate and tropical forests for a long time and there are many proven systems and pieces of equipment readily available. In your particular case you should be sure that good service and spare parts are available. A good indicator is which manufacturer or dealer has the most machines out working in the forest. I have seen an area where almost every skidder that is manufactured was represented but many were lying idle. (When a dealer sells only one machine he cannot afford to have much service and a big stock of spare parts.) In another area one machine dominated all the others and the dealer's service was excellent.

The mechanical capability of your personnel or the people in your area may influence your choice of high, medium or low mechanization. Similarly, your expertise in all the preparatory phases such as road layout and construction, to name one, must be considered when selecting systems or equipment.

Fixed costs have a direct relationship to the amount of time worked and thus productivity. If your machines are susceptible to poor soil conditions and are lying idle you have either to find another type of machine which may extend your working period or modify what you have, with chains or low ground pressure tracks for example. If all else fails and you still want to operate you can resort to double shifting in order to bring your operational hours up to your first expectations. Many operations now load and truck in two shifts, thus cutting original capital layout and lowering fixed costs. In some temperate areas they even log under floodlights just to keep those expensive machines producing.

Wear and tear is a factor to be thought of when ordering equipment. This can come about through misuse and/or through the soil and other weather conditions prevalent in an area. For instance, crawler tracks normally need turning at about 2 500 hours and a complete rebuild is needed at some 4 000 hours. This could change drastically for the worse if you are working in sandy soils. Similarly truck tyres will wear out a lot faster on laterite and crushed hard rock than on sand or clay, and overloading trucks can seriously shorten their useful life.

In closing this section let me reiterate that service is one of the most important factors to be considered when selecting equipment.

We have now taken a quick tour through the basic principles or factors which any prudent operator must take into account when selecting his logging equipment.

You may have noted that knowhow and training were mentioned throughout the paper and I should like to stress these.

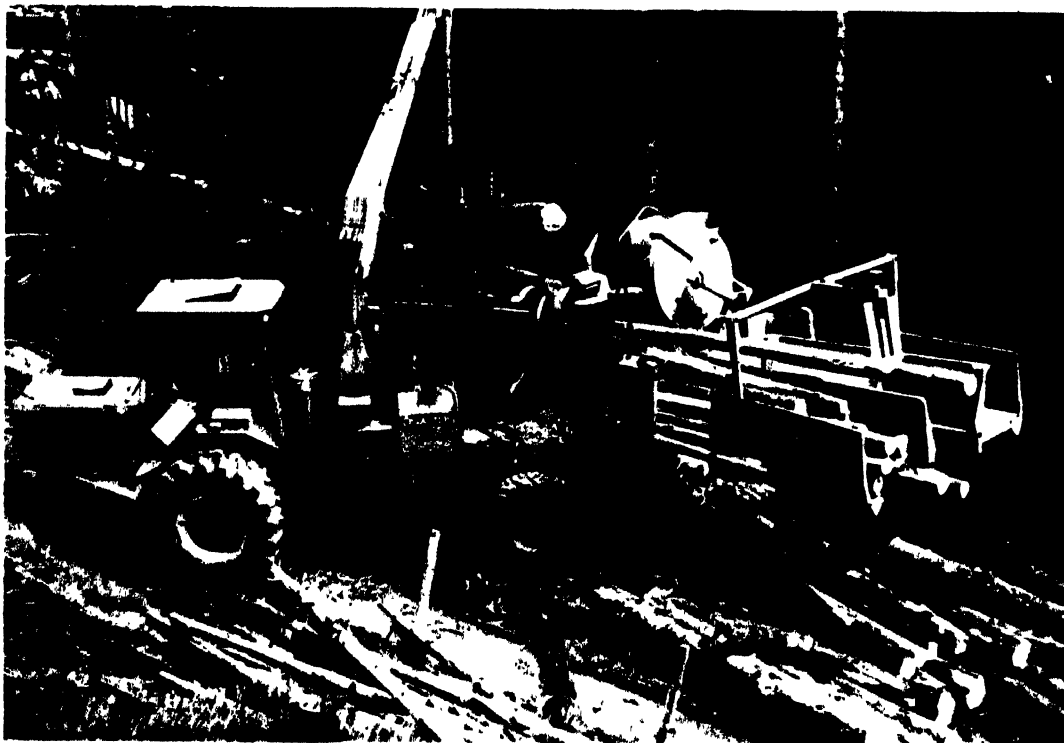
A system implies a planned method of logging. Therefore planning an operation is the key to its success or failure. To have the best chances of success you must have trained, qualified people doing your planning from the first, not halfway through the exercise when corrective action will come too late. People become qualified through training, whether it be through experience or on-the-job training, or through formal training supplemented by experience.

If training is not available an effort must be made to get a training programme started as soon as possible for there is a lag between the completion of training and making use of the training through experience. Training covers the whole range from the simplest to the upper levels of academia and its importance should be recognized for your overall operation as well as for individual phases of machine operation and operating techniques (such as felling).

An operation which starts with poor planning followed by selection of poor or incorrect equipment and the use of untrained operational personnel will have less chance of becoming profitable than a well planned one, and often it cannot be put right because of built-in problems that cannot be eradicated.

Above all you must remember that logging is one part of the forest industry, which covers the field from seedling to market. Don't do as some have done: build a mill, then ask if there are any trees and what they will cost at the mill gate.

Many countries do not have the necessary logging expertise nor the facilities to train people in the requisite skills. I would like to inform you that we at FAO have a considerable amount of expertise to draw upon, and that our primary task is to help Member Nations to the maximum. If you qualify for our assistance, do not hesitate to contact the appropriate division in the Forestry Department of FAO in Rome, especially the Forest Industries Division.



Steyr-Osa processor 705 at work delimbing and bucking  
(Photo: E. Pestal)

## MEDIUM TECHNOLOGY IN WOOD HARVESTING

by

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### 1. INTRODUCTION

In the last few years in many industrialized and developing countries throughout the world a significant change in the role of forestry vis-à-vis the public at the county or country level has taken place as far as utilization patterns, the formulation of forest policies and future action programmes are concerned. In the past, forests in most countries were primarily managed to satisfy the needs of forest industries. Only in recent years has there been an increasing awareness of the importance of the role of forestry in the environment. Now it seems that, at least in many developing countries, the production of wood for energy (fuelwood, charcoal and/or wood gas) has become more and more important. Quite a number of forestry departments have therefore launched large-scale afforestation programmes to satisfy local and/or regional needs. In many developing countries, FAO has established a programme called "Forestry for Local Community Development" (FLCD) to support this movement by involving the masses of the rural population.

Developed countries are also thinking of the establishment of the so-called energy forests to study costs of harvesting wood for energy use (for instance in Austria and Sweden).

This change has been determined by two main factors; the ever-rising oil prices and the foreseeable scarcity of natural oil and the increased needs of an expanding world population. Now you will wonder what all this has to do with forestry in general and logging in particular. Due to the high inflation rates in many countries all over the world, cuts in costs and reorientation in production are required in many sectors of trade, industries and services. As far as logging is concerned, many developing countries are seeking advice on how to cut down investment costs, logging costs and fuel costs. To put it in general terms, how to cut down wood production costs. On the other hand, in many developing countries there is a need for increased employment, especially in the rural areas. Very often the above-mentioned objectives can be achieved by scaling down the logging machinery to be used, by improving the organizational structure, by giving specialized training and by maintaining machinery and equipment properly.

### 2. LEVELS OF WOOD HARVESTING OPERATIONS

Three major levels of harvesting operations can be distinguished:

- Labour-intensive logging;
- Intermediate-technology logging;
- Fully mechanized logging.

## 2.1 Labour-intensive logging

In this type of operation, manual labour is the main input. With the help of good quality and appropriately maintained forestry handtools, developed for the different types of forestry work, quite remarkable results can be achieved in wood harvesting operations. Very specialized labour-intensive methods for moving logs have been developed in various parts of the world; some of these are still being practised, especially where manual labour is cheaper than machinery. Just to give a few examples, in mangrove and freshwater swamps, logs are moved by hand in man-made water channels and ditches; on level soft soils skid trails are often prepared in order to roll logs to landings; in steep terrain with the help of hookeroons or peavies logs are moved downhill, sometimes using skid pans, sledges and chutes. In some instances, animals have partly replaced the purely manual logging systems.

## 2.2 Intermediate-technology logging operations

With intermediate technology only limited manual labour is used and machinery is introduced to facilitate the work and improve production. For instance, in felling, the handsaw is replaced by the chainsaw, whereas for debranching the axe is still often used. For off-the-road and on-the-road transport, farm tractors with forestry attachments (winches, trolleys, cable-crane attachments and trailers) will do an adequate job in many cases. The limiting factors for the introduction of these types of intermediate machinery are very often the size of trees and conditions in the forest (terrain, soil, and road-net density).

## 2.3 Fully mechanized logging operations

In most industrialized countries a high level of mechanization is generally applied, this being dictated by the high cost of labour and the need to guarantee a large steady supply of logs to established forest industries and consumer markets. But in some developing countries we can also find highly mechanized logging operations, especially in tropical forests where the trees are large and logs are too heavy to be handled by small machinery and where labour is not available in sufficient numbers.

In developed countries, in easy terrain, mechanization of large-scale harvesting operations has advanced to such an extent that a single machine now carries out the various jobs of felling, debranching, bucking and debarking. In difficult and steep terrain, however, several machines are still required for the production of logs. Often the following sequence of machines is used: chainsaws for felling, cable cranes to extract the trees and transport them to the roadside, skidders to transport them to the landing and a processor to delimb, buck and debark them before they are loaded on to trucks.

In tropical forests nowadays felling is carried out primarily by heavy-duty chainsaws, and extraction of logs by a combination of crawler tractors for pre-bunching logs and heavy-duty articulated wheeled skidders for the main skidding. In recent years a new machine, the tracked skidder, has been developed to work along with crawler tractors in wood extraction.

### 3. APPLICATION OF INTERMEDIATE TECHNOLOGY

The concept of using intermediate technology in forestry operations and especially in logging (extraction and transport) derives mainly from the changes in the economic situation of many countries, especially with regard to the consumption, use and costs of energy. It also originates from an awareness of the need to preserve forest resources through improved environmentally-oriented efficient operations and to increase forest resources through new plantations. Careful consideration must be given to choosing the correct size/power (kw) of machines because of the high fuel costs in non- or limited oil-producing countries on the one hand, and because of high labour costs in industrialized countries on the other. For this choice one has to take into consideration manpower availability and needs in order to come up with more economic solutions. This is particularly important where newly established forests are to be used for energy production.

### 4. REVIEW OF INTERMEDIATE-TECHNOLOGY LOGGING MACHINERY

When we speak about intermediate technology, we are thinking basically of the agricultural tractor (with a power supply of 50 to 80 hp) with special forestry attachments which have been developed for various jobs in logging and transport operations. This type of equipment is produced mostly in developed countries and is already widely used. However, it is still little known in developing countries.

One aim of this paper, therefore, is to give you an overall view of existing logging equipment available for use with agricultural tractors which meet some of the logging requirements in your country. A second aim is to report on a comparative time study carried out in Mexico in which simple and intermediate logging technology and tools, equipment and machinery were used.

An agricultural tractor for forestry work should have the following:

- Four-wheel drive with a roll-over protective structure or safety cab;
- Three-point linkage (except for those forestry attachments which are directly mounted on the tractor);
- Power take-off;
- Bottom safety shield (a pan to protect the engine);
- Power source of 50-80 DIN<sup>1/</sup> hp.

Attachments for forestry work in present use may be essentially grouped as follows:

- Tractor-mounted grapples for skidding logs and shortwood;
- Tractor-mounted winches with or without logging plate;
- Tractor-attached winches with or without logging plate;
- Tractor-attached logging trolley or bogie;
- Tractor-attached mobile tower cable cranes;
- Trailers for transport of logs and shortwood.

In addition to these, independent ground skidding winches (with or without radio or remote control) have been developed and refined in recent years. Another remarkable innovation is the polyethylene chute which is used to slide pulpwood and firewood downhill.

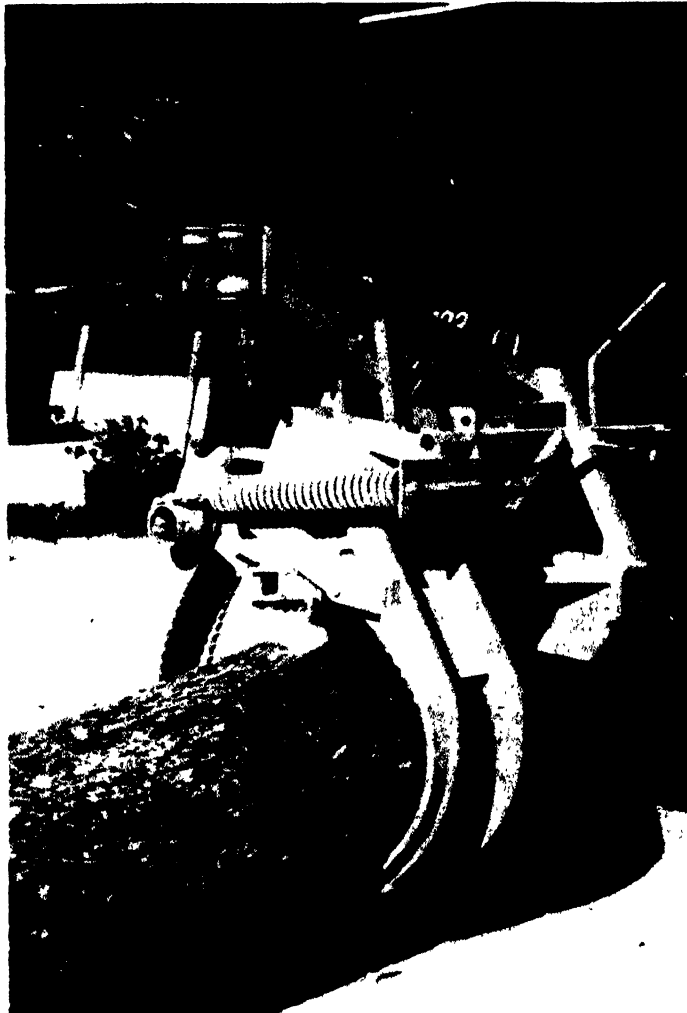
#### 4.1 Tractor-mounted grapples for skidding logs and shortwood

The tractor-mounted grapple attachment is very useful for a one-man operation in easy terrain. The use of this grapple usually requires that the tractor be able to move toward the felled trees or logs to pick them up near the stump; however, some grapples are equipped with a winch for more difficult terrain. Normally, the grapple can handle everything from very small to quite large trees and logs (for example, poles, trees and logs with diameters ranging from 8 cm up to 110 cm).

A few firms which manufacture grapples and tractor attachments are given below:

For log skidding: Farmi, Kuxmann, Ruttnig, Loft;

For shortwood skidding: Norgaard, Kärntner Maschinenfabrik.



Tractor-attached grapple with a single-drum  
cable winch (Photo: FPP <sup>1/</sup>)

1/ Kooperationsabkommen zwischen Forstwirtschaft, Platten-u. Papierindustrie



The winch has a power line pull of 4 000 kp, with a cable capacity of 60 m when using a 12 mm Ø cable. The medium cable speed is about 0.5 m/sec. The whole attachment, without the cable, weighs about 470 kg.

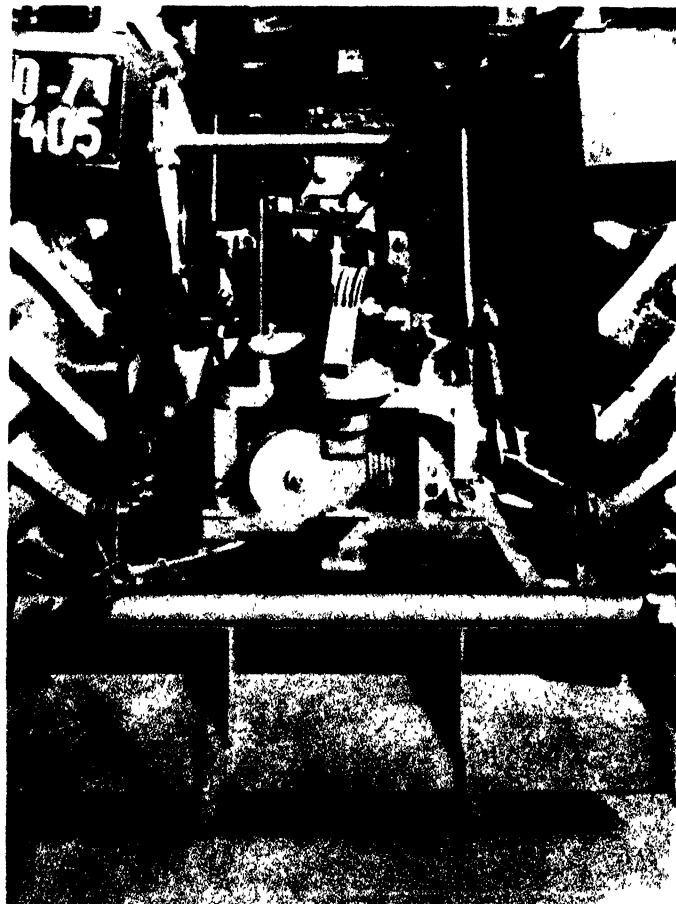
Purchase prices for different types of grapples range from approximately US\$ 2 000 to US\$ 5 000<sup>1/</sup>, depending on whether they are required for light or heavy duty.

#### 4.2 Tractor-mounted winches with or without a logging plate

These are winches which are directly mounted on to the rear of a tractor at the factory.

There are various companies which manufacture tractor-mounted winches, such as Adler, Glogger, J.H.B. Hydatongs, Huber and Gland, Lindner, Kuxmann, Nagel, Oesa, Ritter, Schlang and Reichart, Vögerl and Werner. They are either single- or double-drum winches with a maximum line-pull capacity ranging from 2 400 to some 8 000 kp.

Most of the winch drums have a cable holding capacity of 50 to 80 m, but some have a capacity of 120 m; generally 12 to 14 mm Ø cables are used. Purchase prices range from some US\$ 4 000 to 8 000. The picture below shows a single-drum winch with a logging plate (Vögerl) produced by Rittmann Maschinenbau.



Tractor-mounted single-drum winch with logging plate

(Photo: FPP)

<sup>1/</sup> All purchase prices quoted are only approximate, generally from 1979 and 1980, and are given for information purposes only. They should be understood as ex-factory prices

The winch has a maximum line pull of 3 500 kp with a cable capacity of 110 m when using a 12 Ø cable. A logging plate, as shown in the picture, is recommended for operational and safety reasons.

#### 4.3 Tractor-attached winches with or without logging plate

These winches are attached to the tractor's three-point linkage, have single or double drums and are often equipped with a logging plate. Some of the winches have drums which are located parallel to the tractor's axles; others have them at right angles to the axles. The latter type of winch needs a special fair lead. Instead of a logging or skidding plate, one manufacturing company produces a simple frame with bunks to stabilize the tractor while winching in the logs.

Some of the well-known brand names of tractor-attached winches are as follows: Farmi, Huber, Igland, Krasser, Norse, Ritter, Schlang and Reichart, Schwedenforst and Vögerl.

Winches generally have a maximum line pull which ranges from 1 500 kp to 5 000 kp. Maximum extraction distances for winching are 50 to 180 m depending on the size of winch and cable used. Cables of 8, 9, 10, 11 and 12 mm Ø are used for winching purposes, the most frequently used being the 12 mm.

Prices, depending on make and/or power required, range from approximately US\$ 1 200 to US\$ 7 000.

A picture of a very simple winch, the Farmi winch with a grapple, is shown below.



Wheeled tractor with Farmi winch and grapple

(Photo: NORMET)

This winch has a line pull capacity of 3 000 kp, with a cable drum capacity of either 50 m when using a 8 mm Ø cable, or 75 m with a 10 mm Ø cable. Purchase price is about US\$ 1 700.

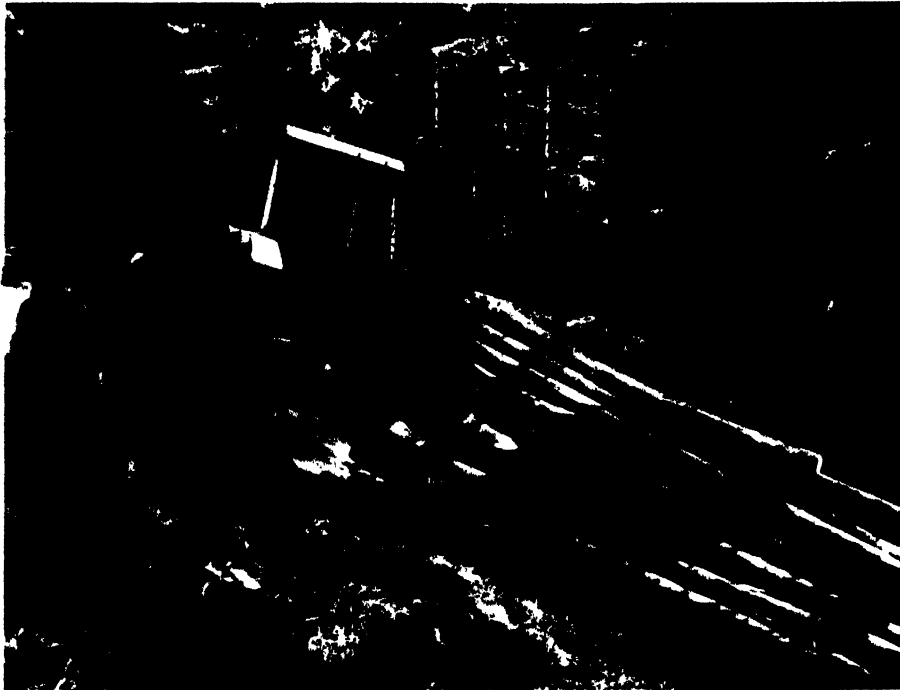
#### 4.4 Tractor-attached logging trolley (bogie)

This tractor attachment is produced by Steyr and by Schlang and Reichart, for instance. It is essentially a small trailer with two wheels, a single-drum winch and a skidding plate. The function of the logging trolley is a double one, namely to winch and to transport. Winching distances can be either for a maximum of 75 m (12 mm Ø cable) or 110 m (10 mm Ø cable).

The maximum line pull is about 4 000 kp. The interesting aspect of this machine is that the log can be winched in from difficult ground and terrain to a skidding trail or forest road along which the logs can then be skidded to the road or landing. While the skid plate serves as a safety protection structure in the first operation, it acts as a transport aid by carrying one end of the logs during the skidding phase (see photographs). The purchase price for the Steyr logging trolley is about US\$ 5 500.



Farm tractor with bogie used for uphill ground skidding  
(Photo: Steyr)



Farm tractor with bogie transporting the load (Photo: O. Sedlak)

#### 4.5 Tractor-attached mobile tower cable cranes

There are quite a number of cable systems on the market, which are built to be used as attachments for agricultural tractors in cable-crane operations, such as James Jones, Koller, the Urus mini and one which is just now under investigation: the Igland/Kubota system. The advantage of these over the traditional cable systems is the considerable reduction in rigging time afforded by the mobile tower cable equipment. Thus logging can be carried out in steep, difficult, marshy or swampy terrain more economically than the older methods allowed. As their spans are generally from 300 to 500 m in length, these systems are an ideal supplement to a basic road network designed to make forests entirely accessible for harvesting purposes. One can distinguish two different types of cable system: the high lead and the skyline. The different cable systems are explained in detail in other papers and therefore will not be discussed further here.

The above-mentioned machines are essentially used in plantation forests, for small-sized wood in clear fellings or thinnings. They are able to transport a maximum payload of 1.5 tons of logs.

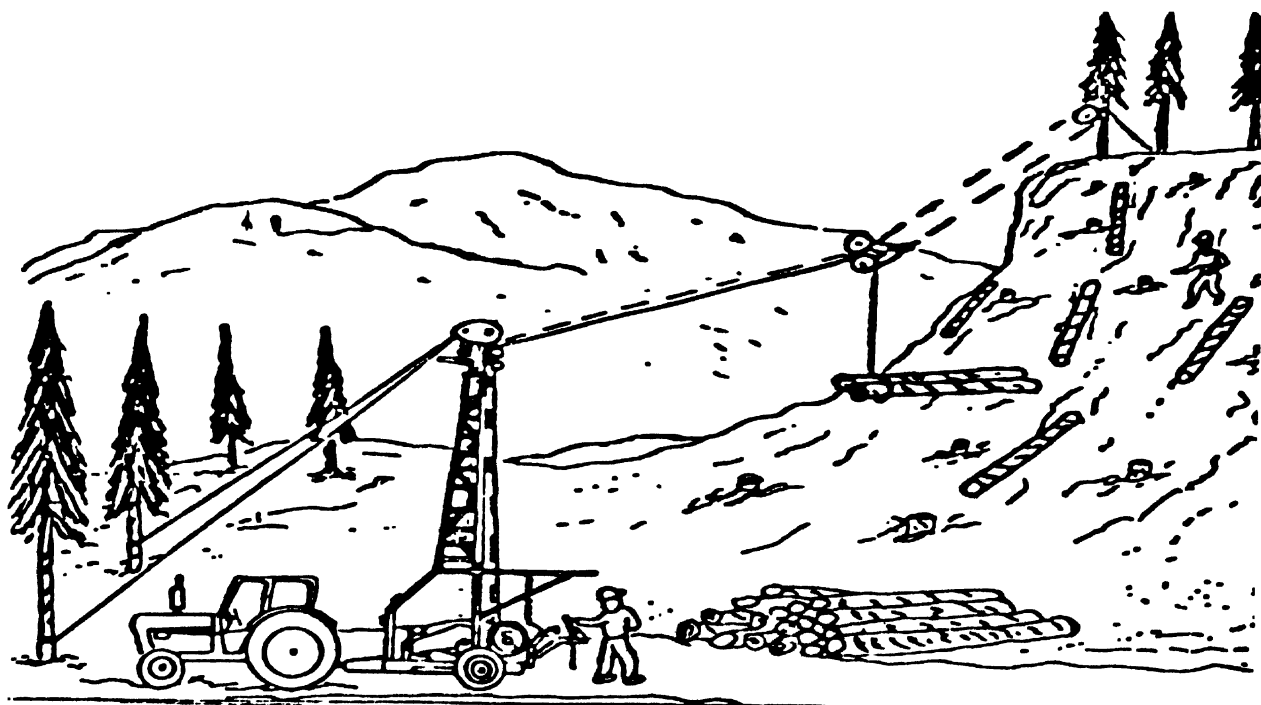
A Koller cable system, for instance, costs about US\$ 30 000. The James Jones will cost about US\$ 50 000. In addition, an agricultural tractor will still have to be purchased to operate either system.

The following two pictures show two different cable systems in operation.



Koller 300 cable system extracting logs uphill to the roadside

(Photo: FPP)

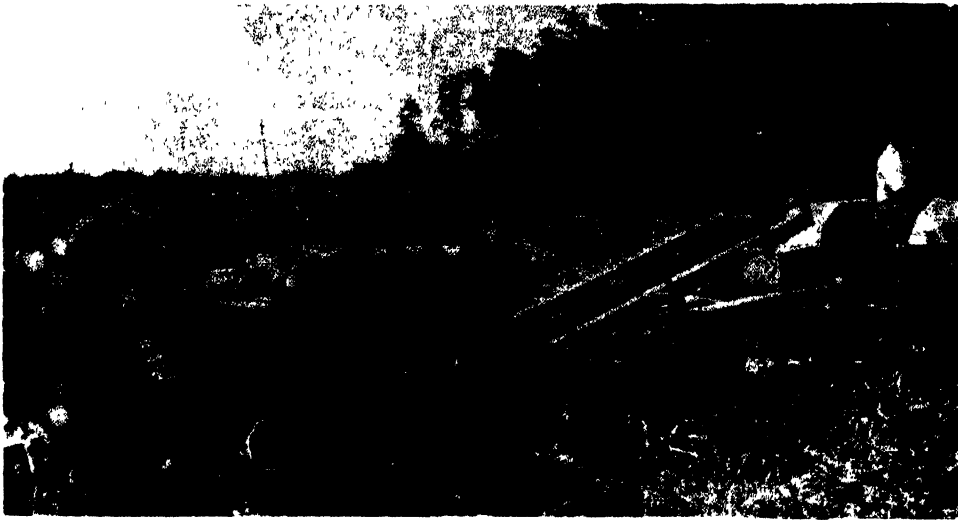


James Jones trailer Alp cable system extracting logs downhill to the road  
(Picture provided by James Jones)

#### 4.6 Trailers to transport logs and shortwood

Trailers for agricultural tractors are essentially designed for farmers and small contractors using tractors to transport logs or shortwood over short distance. Special trailers like the Radolf-Zeller Rückewagen, which has a hydraulic tilting device to make unloading easy, have been developed to transport shortwood.

This trailer is single-axle with a load capacity of 2 steres if the shortwood is bundled; or 3 to 4 steres, if the wood is loaded loose. The length of the wood (1 or 2 metres) is also a factor. The purchase price of the trailer is about US\$ 5 500.



Unloading shortwood which has been transported (Radolf-Zeller-Rückewagen)

The same manufacturer also produces a single-axle trailer for transporting poles, with a maximum loading capacity of 3 tons.

#### 4.7 Ground skidding winches

Independent ground skidding winches are designed for extracting logs from difficult areas such as gulleys, creeks, ravines and broken terrain in small-scale operations. They are also designed for extracting small-sized timber from plantation forests. Depending on the make, their line-pull capacity ranges from 600 kp to 2 200 kp. They are able to cover extraction distances which range from 80 to 165 m. Cable diameters of 5 mm, 6 mm, 6.5 mm, 7 mm, 8 mm and 9 mm are generally recommended. Some of the winches are equipped with a power chain saw engine, others with their own brand. The available hp for various winches ranges from 4.5 to 16 DIN hp.

Their weight varies from 42 kg to 560 kg. The 42-kg winch can easily be carried by hand, whereas the others must be transported by other means to the working area.

The winch is generally tied to a tree; the logger then has to pull the cable to the log, choke the log and then, by means of radio control, winch it in. An exception is the Akja winch. This is built on a sledge. One end of the cable is fixed to a tree and the winch is moved to the log to be extracted; the log is put on the sledge and winched in to the landing on the sledge.

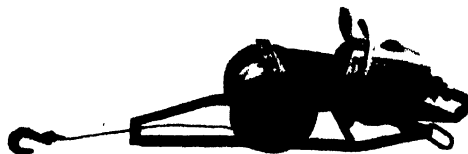
One manufacturer produces a ground skidding winch with an engine on a small single-axle trailer; winch and engine are linked by hydraulic hoses. The trailer can be moved by hand to the place where log extraction is to take place.

Purchase prices for the above-mentioned winches range from US\$ 2 500 to 12 000, depending on the type and make.



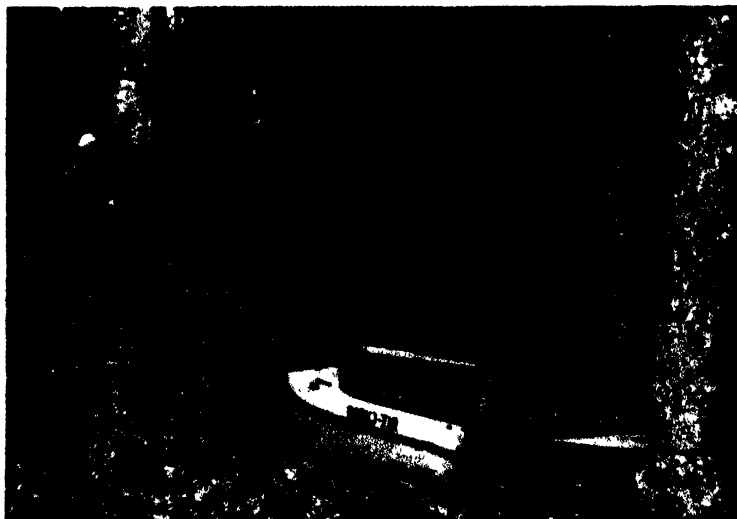
Akja sledge winch  
(Photo Kärntner Maschinenfabriken Egger Ges.m.b.H.)

The sledge winch is generally used for prebunching of logs; however, it is also very useful for transporting cables and cable crane support material to installation sites in the forest area. Another application is for placing polyethylene chutes in thinnings. The sledge winch is equipped with a 4.8-kw chainsaw engine, with a line pull of 800 kp, a 110-m cable (6.5 mm Ø) having a total weight (including cable) of 70 kg. This winch costs about US\$ 2 500.



Multi KBF lightweight ground skidding winch  
(Photo KWF 1/)

The Multi KBF lightweight ground skidding winch is equipped with a chainsaw engine (Jonsereds) of 4.2 kw, with a line pull of 1 000 kp and a drum capacity of 80 m with 6-mm cable, or 150 m with a 5-mm cable.



Radiotir Alpin 1 200 (Photo KWF 1/)

The Radiotir Alpin 1 200 winch is used with radio control and can be operated by a single man. It is equipped with a 6 kw engine, and has a line pull of 1 200 kp and a cable drum capacity of 165 m when 7 mm Ø cable is used or 125 m when 8 mm Ø cable is used. Its purchase price is approximately US\$ 9 000.

##### 5. CASE STUDIES ON INTERMEDIATE LOGGING TECHNIQUES IN MEXICO

The objective of the studies was to identify intermediate logging techniques which would improve efficiency in wood harvesting for farm forest owners. The intention was to reduce manual labour by introducing appropriate low-capital-investment machinery and so make logging operations more economic for the worker, the contractor and the entrepreneur.

Altogether a series of eight different studies with various degrees of mechanization were carried out, taking into consideration silvicultural requirements as well as terrain features. The studies took place in the coniferous forests near Perote, Veracruz, at an altitude of 2 400 to 3 000 m above sea level. The predominant species were pines, mixed with Abies sp. and cypress.

The ground conditions ranged from flat to steep terrain with average slopes of 3 to 55%. The average DBH 2/ of the trees removed during the tests ranged from 18 cm to 28 cm. Both clearfelling and selective cuts were performed. Investigations were carried out by time studies for which the multimoment method was selected. The results obtained were evaluated using a computer programme developed by the study team.

1/ Kuratorium für Waldarbeit u. Forsttechnik

2/ Diameter at breast height



Through time studies the productivity and cost of various methods were evaluated and a comparative cost estimate for the different extraction methods was developed. Eight different logging methods were studied, as follows:

1. The conventional logging operation, felling and crosscutting with handsaw and axe and skidding with a pair of oxen.
2. The same as above but with more efficient hand tools given to the workers who had been trained for a brief period.
3. Felling by handsaw and tree-length skidding by wheeled tractor equipped with a double-drum winch (Igland 5000).
4. Felling and crosscutting by chainsaw, extraction in two different ways:  
Variation 1: wheeled tractor equipped with double-drum winch;  
Variation 2: wheeled tractor equipped with a shortwood trailer.
5. Felling by chainsaw, extraction of tree-length logs by wheeled tractor equipped with a bogie.
6. Shortwood thinnings with felling by handsaw and manual extraction.
7. Shortwood with felling by chainsaw and extraction using a polyethylene chute (Leykam logline).
8. Logging in steep terrain with felling by chainsaw and extraction by cable crane.

Based on the experience of these tests the following conclusions can be drawn.

The traditional logging system can certainly be improved by providing work-oriented training to forest workers and small farm-forest owners and/or logging contractors, as well as by introducing improved and properly maintained tools.

As far as extraction and transport methods are concerned, the manual method is the most expensive one. Traditional animal skidding, especially for shorter distances, is still compatible with extraction performed by a wheeled tractor equipped with a winch. This is particularly evident when operators are not sufficiently trained.

Extraction by farm tractor equipped with bogie turned out to be the cheapest of all intermediate technology methods tested.

The studies gave a clear indication that, in countries with low or rather low labour costs, a high level of mechanization may not be justified economically. The level of mechanization, type of machinery and required kw engine power, therefore, must be matched with the country's socioeconomic background, always taking into consideration the characteristics of the forest and the environment (size of operation, tree stands and sizes, felling area, terrain, soil, infrastructure, manpower availability).

The basic data of the results obtained are presented in the two tables that follow. Table 1 gives the productivity in  $m^3$  per manhour and costs per  $m^3$  in US\$ for the various operations. Table 2 shows comparative extraction costs calculated per  $m^3$ , in US\$, for a skidding distance of 50 m.

Table 1  
TIME STUDY RESULTS IN THE PINE FORESTS OF PEROTE/VERACRUZ

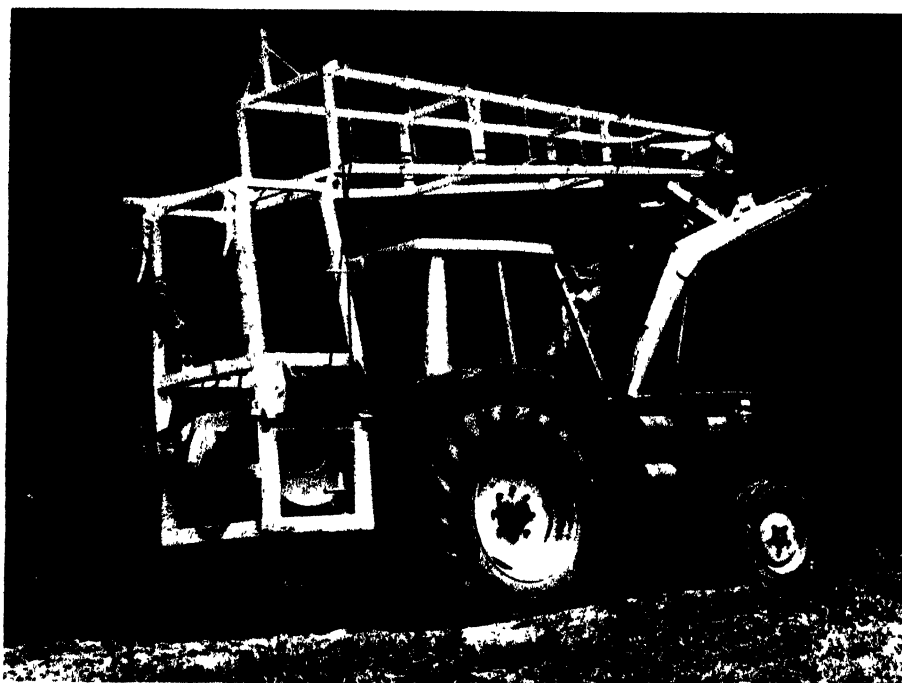
Study	Average slope	Average DBH	Felling cut intensity	Type of operation	Equipment used	Production in m <sup>3</sup> per manhour	Costs in US\$/m <sup>3</sup>	Average extraction distance
Study No. 1								
Conventional assortment method	3%	27 cm with bark	91% of total volume per unit area	Felling & crosscutting	Handsaw and axe	0.77	0.76	50 m
				Extraction	Pair of oxen	1.19	1.23	
						Total	1.99	
Study No. 2								
Conventional method, but new tools and training of workers	3%	27 cm	80%	Felling & crosscutting	Handsaw and axe	0.97	0.64	50 m
				Extraction	Pair of oxen	1.33	1.11	
						Total	1.75	
Study No. 3								
Tree-length method	5%	28 cm	77%	Felling	Handsaw and axe	1.99	0.31	80 m
				Extraction	Wheeled tractor with winch	2.63	2.85	
				Crosscutting	Handsaw and axe	0.65	0.94	
						Total	4.10	
Study No. 4								
Mechanized assortment method	4%	28 cm	86%	Felling & crosscutting	Chainsaw and axe	0.87	2.01	Var. 1:100 m Var. 2:350 m
				Extraction: Variation 1	Wheeled tractor with winch	1.71	2.37	
				Variation 2	Wheeled tractor with trailer	0.54	4.12	
						Total 1	4.38	
						Total 2	6.13	
Study No. 5								
Tree-length method	3%	26 cm	84%	Felling	Chainsaw and axe	1.76	1.65	150 m
				Extraction	Wheeled tractor with bogie	2.50	3.02	
				Crosscutting	Chainsaw and axe	2.74	1.05	
						Total	5.72	
Study No. 6								
Shortwood method in thinnings	15%	18 cm	10%	Felling & crosscutting	Bowsaw and axe	0.28	2.28	30 m
				Extraction	Hookroons	0.50	1.17	
						Total	3.45	
Study No. 7								
Shortwood method in thinnings	20%	19 cm	15%	Felling & crosscutting	Chainsaw and axe	0.41	3.78	60 m
				Extraction	Polyethylene chute	1.06	1.85	
						Total	5.63	
Study No. 8								
Assortment method in steep terrain	55%	26 cm	40%	Felling & crosscutting	Chainsaw and axe	1.18	1.49	80 m
				Extraction	Wheeled tractor with cable	0.58	4.22	
						Total	5.71	

Table 2  
COMPARATIVE COSTS OF WOOD EXTRACTION FOR A 50 M DISTANCE

Study	Method	Extraction cost per m <sup>3</sup> , in US\$
No. 1	oxen skidding	1.23
No. 2	oxen skidding (better tools, some training)	1.11
No. 3	wheeled tractor with winch (untrained personnel)	1.78
No. 4	wheeled tractor with winch (trained personnel)	1.19
No. 5	wheeled tractor with bogie <u>in thinnings</u>	1.01
No. 6	manual extraction <u>in thinnings</u>	1.95
No. 7	extraction by chutes	1.54



Cone-type mechanical wood splitter attached to wheeled tractor  
(Photo: R. Heinrich)



Agricultural tractor equipped with K300 cable equipment  
ready to be shifted to next cable-crane setting

(Photo: E. Pestal)



Power-saw winch for prebunching individual  
logs from inaccessible areas

(Photo: E. Pestal)

## COST CALCULATIONS IN LOGGING

by

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## 1. PRELIMINARY REMARKS

Logging is an economic activity geared to attaining specific objectives. Various alternatives in both methods and equipment may be employed to reach these objectives. As the decision on which alternative should be used will depend on the objectives, the latter must be clearly stated and understood for each logging project. Normally, the main criterion for the decision will be efficiency, which may be defined as "reaching a desired objective at the lowest possible cost". In this definition, the term "objective" must include not only the production of logs but also protection of the forest and the environment and all other constraints that apply to a logging operation.

Logging technology has changed considerably in recent decades. Manual labour has been increasingly replaced by machinery - mostly expensive machinery. At the same time, wages for forest labour have increased much more than have prices for logs. Consequently, further mechanization has been considered necessary as part of a programme to reduce costs or, at least, to ease or delay cost increases.

As mechanization progressed, each new step required more capital and each mistake became more costly. Mechanization was found to have not only a short-term effect on costs and profit but also a negative effect on soil and stand - an effect which has been frequently neglected. For these reasons, a thorough knowledge of all aspects of the costs and benefits of the various alternatives for logging - existing and proposed - became necessary. Only by comparison of the costs and benefits could safe judgements be made on the various alternatives. From this, a system of cost accounting developed which will be discussed in the following chapters.

At this juncture it should be pointed out that substantial social, economic and technological differences exist between the countries and the regions of the world and transferring a cost accounting model from one to another is possible only to a limited extent. Even enterprises in the same country may need different systems depending on their size, organizational level, degree of mechanization, etc.

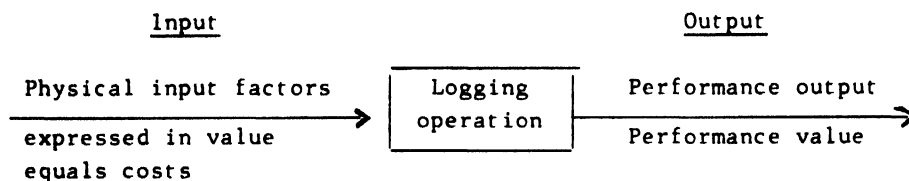
Even though basic principles may be transferable, the individual conditions and objectives for each enterprise must be considered. It is the purpose of this paper to offer guidelines, to point out major aspects and problems of cost accounting and to try to show what it is all about.

## 2. CONCEPTS, ELEMENTS, FUNCTIONS AND OBJECTIVES OF COST ACCOUNTING

2.1 The cost concept

The term "cost" has so many meanings and applications that two people discussing cost may have quite different things in mind. Therefore the cost concept as used in this paper must be explained.

Any activity in wood harvesting requires the employment of goods and labour in an appropriate combination. The money equivalent of these inputs is called cost. Costs are therefore defined as "values used to obtain performance". They are made up of two components - the amount and the price of the input factors.



All economic activity requires continuous analysis and control of costs and performance. This can be done by cost accounting. Cost accounting includes determination, allocation, classification, processing and control of costs. Cost data are determined by pre-calculation, intermediate calculation, and recalculation. Pre-calculation precedes the performance of a project, recalculation follows it. Intermediate calculation is used to check and amend pre-calculated values.

## 2.2 Functions and objectives of cost accounting

These are manifold. Cost accounting should primarily provide the basis for decisions in logging such as:

- planning and selection of most appropriate logging methods and systems, assessment of alternative systems and engineering variants;
- planning of individual investments and investment projects (new investments: change from manual work to machinery; replacing investments: replacement of old machines by new ones);
- price determination: determination of prime costs as a price basis for all logging contracts (ancillary firm units, subcontractors), determination of lowest price levels at which logging contract can still be accepted, transfer pricing;
- agreements with subcontractors (logging firms and farmers);
- decision whether to carry out logging operations within the company or to hire subcontractors;
- determination of stumpage price from the timber market price (off-the-road basis);
- management and budgeting: e.g. management with objectives, determination of objectives, cost budgeting;
- continuous revision of cost formation and cost development as a basis for internal disposition, assessment of present systems and comparison with potential new ones.

Cost analysis is concerned mainly with cost elements, cost centres and cost units.

## 2.3 Types of factors employed - cost elements

Depending on the kind of input factors employed there is a traditional distinction of costs into labour costs, costs of resources (capital costs), outside service costs, and tax costs. Resources are divided into long-term assets which serve utilization and

short-lived goods which serve consumption. Long-term assets are subdivided into depreciation investment goods (e.g. road-net, buildings, machinery, transport vehicles) and non-depreciating investment goods (e.g. land). Depreciating goods require special cost-accounting consideration.

Large Austrian forest enterprises (those with more than 500 ha of forest area in production) reported the following distribution of cost elements in logging:

<u>Cost element</u>	<u>Percent</u>		<u>Change</u>
	<u>1970</u>	<u>1980</u>	
Labour	69	58	- 11
Resources	15	19	+ 4
Subcontractors	16	22	+ 6
Taxes	-	1	+ 1
	<u>100</u>	<u>100</u>	<u>-</u>

Logging costs

AS/m <sup>3</sup> 1/	177	360	+ 103%
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The above table does not include costs of forest roads or of administration and management. Wage costs have been increasingly replaced by costs for resources and subcontractors.

The book value of capital in long-term assets in the logging cost centre was AS 26 in 1970 and AS 60 in 1980 per m<sup>3</sup> of harvested timber or AS 110 and AS 255 per ha of productive forest area. The value of forest roads was AS 120 and AS 125 per m<sup>3</sup> and AS 492 and AS 530 per ha.

Analysis of costs by element is important mainly because the cost of elements tends to rise at a different rate. For example, from 1970 to 1980 Austrian wage rates rose by almost 300 percent while purchase costs of power-saws increased by only 60 percent. In the same period, the cost of living increased by 82 percent and timber prices by 112 percent. These differing rates of increase have been the main incentive for mechanization.

#### 2.4 Items to which costs are charged - cost centres

Cost accounting determines not only the cost elements but also where or for what the costs were incurred. For this purpose a firm which is an independent accounting system is subdivided into dependently accountable units, called cost centres. Cost centres are places, phases and reference areas of cost origin. They can be classified according to functional, geographical, organizational or purely accounting criteria.

For cost accounting purposes, logging covers the whole work chain from the tree in the stand to the destination of the log on rail or at a timber processing plant. Road construction and maintenance as well as transport by lorry are included.

#### 2.5 Performance units - cost units

Cost accounting also determines the amount and structure of cost per performance unit or "cost unit". In general, cost units are products or their pre-stages which develop

1/ AS = Austrian shillings AS 17 = US\$ 1

through a performance process and the employment of costs. A cost unit in logging is usually 1 m<sup>3</sup> of felled, logged and/or transported timber. Preliminary cost units could be one machine hour or one man-hour, etc.

## 2.6 Some important cost concepts and aspects of cost classification

Some basic concepts of cost accounting are clarified below:

### a) Unit costs and total costs

Depending on whether costs are related to the product unit or to the total production, the terms unit costs (e.g. cost per piece or per hour) or total cost (e.g. cost per operation or per cost centre) are used.

### b) Fixed and variable costs

Fixed costs are those which are constant in their total amount. They are related to time rather than to activity so that costs per unit of production vary inversely with output.

Variable costs are those which are related to activity rather than to time. They are constant for each unit of production but the total variable cost increases as production increases.

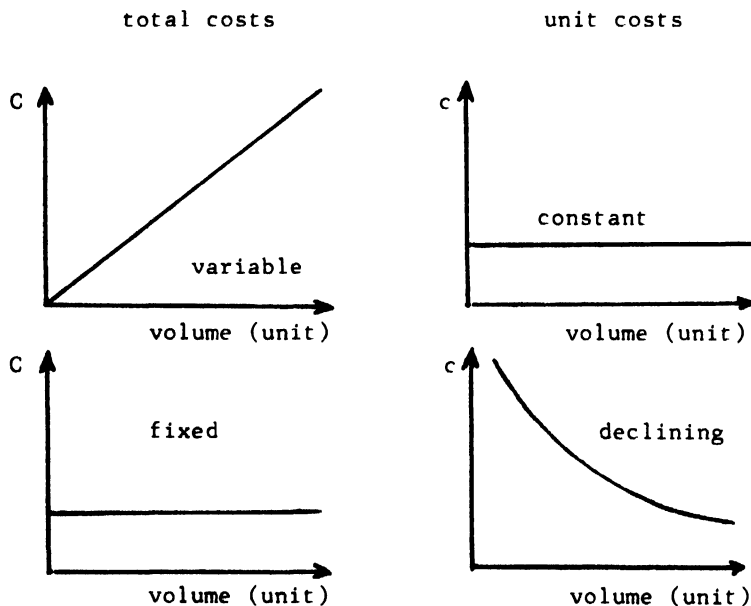


Fig. 1 COST BEHAVIOUR AT VARYING ACTIVITY LEVELS

The distinction between fixed and variable components is important for all decisions influencing costs (e.g. working a machine to more or less capacity by hiring subcontractors or acting as subcontractor for others).

Only variable costs are relevant for short-term decisions.

### c) Direct costs and indirect costs

Depending on how costs are charged to cost centres or cost units, there are direct costs and indirect costs or overheads.



Direct costs can be directly charged to the cost unit because they are caused by very definite performance (e.g. material, labour). As a rule they depend on the level of activity (output) and act as variable costs.

Indirect costs (overheads) are not immediately related to a particular function or activity but influence several cost centres or even the enterprise as a whole. They may be connected with a number of activities or may be related to earlier activities in a production chain. These costs are charged to separate cost centres or cost units according to established allocation criteria.

### 3. INPUT FACTOR AND CONTRACT (JOB-ORDER) ACCOUNTING

#### 3.1 Cost data

If costs are to be determined for any given logging system or operation, input factors and work phases are the basic components to be examined. By definition, costs are the product of input factor quantity and input factor price. This is computed by the formula:

$$\begin{array}{ll} C = Q \times P & C = \text{cost} \\ \text{or } C = \sum q_i \times p_i & Q = \text{quantity} \\ & P = \text{price} \end{array}$$

It is therefore necessary to determine the types, quantities and prices of the input factors employed. All three components are decision parameters which can be influenced to a certain extent.

Different systems and processes can operate with different combinations of input factors and also with different input quantities. Lower input may be the result of good management and lower purchase prices may be the effect of purchasing strategies. With machinery the degree of utilization, and of service and maintenance, is also reflected by input figures.

A short discussion of the sources underlying these three data follows.

To estimate the costs of an operation (project, contract, job) the following data itemized for each work phase and each method are required:

# ACCOUNTING CHART

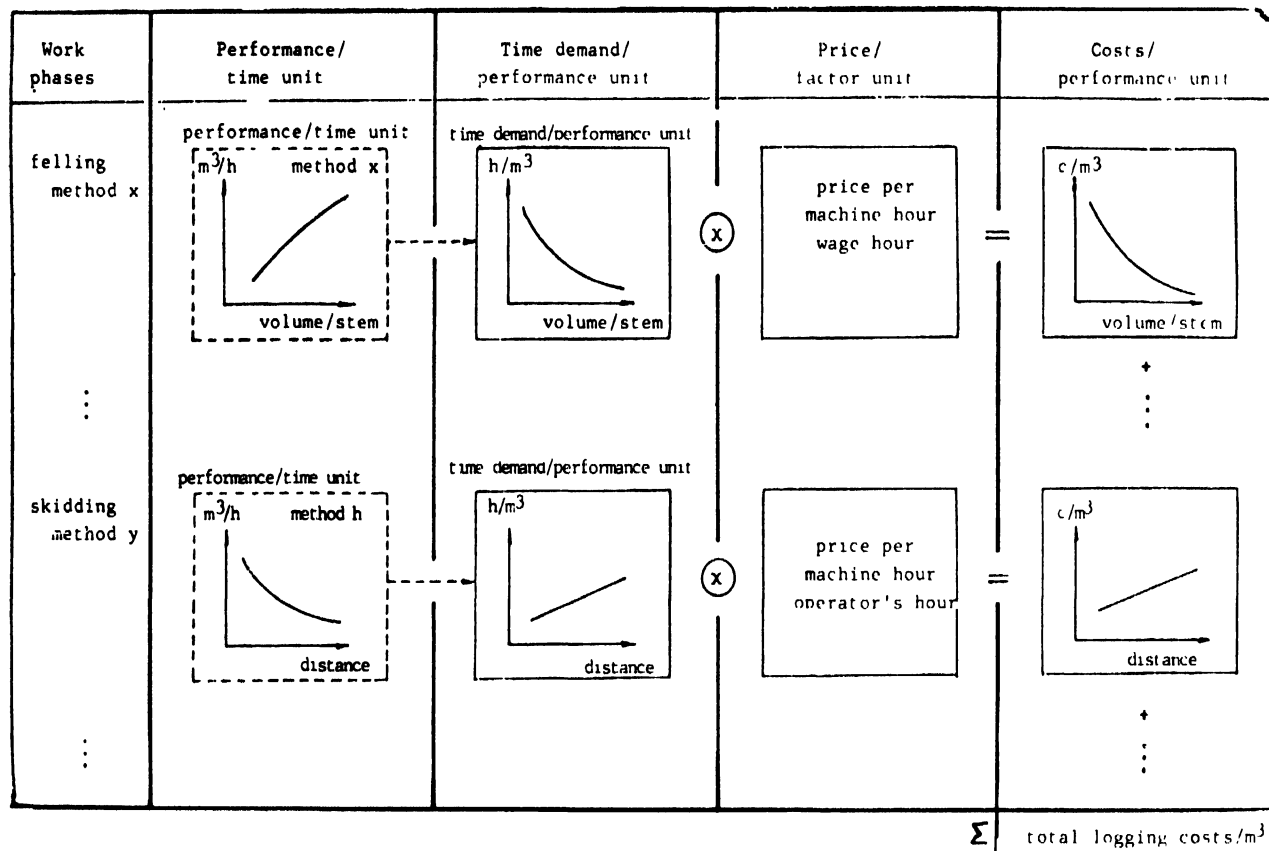


Fig. 2 DIAGRAM OF BASIC DATA AND ELEMENTS OF COST ACCOUNTING FOR A GIVEN LOGGING METHOD (special man-machine combination)

- the types of input factors
- the quantity of input factors per unit of performance
- the price per hour or per unit of quantity
- information on the conditions of logging which affect costs such as timber species, average solid content per stem, skidding distance, skidding direction, terrain conditions, etc.
- volume of activity.

Total costs are determined by multiplying costs per unit of performance by the quantity of performance. Certain overheads (management, supervision, accounting, etc.) have to be added.

### 3.1.1 Data sources

Data on the required quantities can be obtained from tables, diagrams, experience values and special calculations. Austrian examples are guide value tables which have been prepared for felling by power-saw, for beech felling in the Austrian Federal Forest Enterprise, and for logging by wheeled skidder in the AFFE. Evaluations of results obtained in practice are of particular value (piece-rate statistics, etc.). Such data always apply to specific systems and methods (special man-machine combinations). New logging systems require new time studies for a preparation of performance and input data.

### 3.1.2 Site factors and other cost-influencing factors

Any operation is a combination of a wide variety of factors. Some are influenced or controlled by decisions in determining the cost level but there are many that are not controllable since they exist through the choice of an operation site. These, too, have a substantial bearing on logging costs and must therefore be determined. Apart from decidable factors such as logging method, available machinery, training level of staff, dimensioning and combination of work chain, there are also decisive factors such as length of work chain (e.g. with or without debarking), total felling quantity, climate, terrain conditions, tree dimensions and tree species. To know them is vital for estimating and evaluating logging costs. Fig. 8 includes the most important site factors for an actual operation.

Let us have a closer look at two factors shown in the flow chart in Fig.2. In the following paragraphs, the prices per factor unit are determined for

- a) one man-hour of work
- b) one machine-hour

### 3.2 Ascertaining costs per man-hour of work

The cost of a man-hour of work is made up of the wage rate and the incidental labour costs which include remuneration for non-working time and social expenses. The wage per hour may depend on the rate (time-rate, piece-rate, and premium bonus) which has been fixed by employers and employees and is applicable throughout the country, or it may be based on internal agreements. Piece-work wages are linked to individual performance per unit of time.

Incidental labour costs are somewhat more complicated. They are not paid for any direct performance by the employee but rather are paid to comply with legal requirements, collective contracts, or work orders. In addition, an employer may make voluntary payments which go beyond statutory obligations.

Incidental labour costs are found from data obtained in previous years, for example, from a balance sheet, or from estimates based upon experience such as estimate of the effect of sick leave.

Average values from the past are sufficient in most cases but exceptions do occur. In Austria, incidental labour costs range from 60 percent to 130 percent of basic wages. In large private enterprises they were 67 percent in 1970 and 78 percent in 1980; in the Austrian Federal Forest Enterprise they were 81 percent in 1970 and 109 percent in 1980. Since this cost factor is substantial it is continually being examined, analysed and adjusted in cost accounting.

Averaged values fail to account for:

- annual changes in legal provisions such as assessment rates for unemployment insurance, accident insurance, health insurance, etc.
- items such as severance pay which may not be adequately covered in bookkeeping records
- incidental labour costs which may change significantly for different wage rates and working sites.

In some cases, therefore, it is advisable to determine labour cost data in detail.

Figure 3 illustrates a system developed by Flachberger for a roadbuilding and machine centre of the AFPE. It gives an estimate of incidental labour costs expressed as a percentage of basic wage rates and is used as a basis for machine operation, profit and loss accounting, and budgeting.

The table gives only incidental labour costs which are incurred under all normal circumstances. Special costs such as per diem and travel expenses may arise from specific operations at distant felling sites.

Most of the items are linked to gross wages. Some items (statutory social insurance, for example) have assessment limits above which rates remain constant. Items 1 to 8 in the table are variable because they depend on the hourly wage rate. The remaining items, 9 to 23, are fixed as they depend on earnings from the previous year.

Incidental labour costs will sometimes include costs of apprentice training and voluntary payments to employees in addition to the items mentioned in the table.



Felling tools (Photo: FAO)

WAGE/HOUR in AS			50	60	80	100	
			7 000	8 400	11 200	14 000	
GROSS EARNINGS/MONTH (140 hours) in AS			9 670	11 070	13 870	16 670	
VARIABLE INCIDENTAL LABOUR COSTS	1	UNEMPLOYMENT INSURANCE	1.05 % highest assessment basis: 13 800 AS	101.50	116.24	144.90	144.90
	2	ACCIDENT INSURANCE	1.50 % highest assessment basis: 18 600 AS	145.05	166.05	208.05	250.05
	3	SICKNESS INSURANCE	3.15 % highest assessment basis: 13 800 AS	304.61	348.71	434.70	434.70
	4	OLD-AGE INSURANCE	10.25 % highest assessment basis: 18 600 AS	991.18	1 134.68	1 421.68	1 708.68
	5	HOUSING ALLOWANCE	0.40 % highest assessment basis: 13 800 AS	38.68	44.28	55.20	55.20
	6	FAMILY ALLOWANCE	5.00 % no limit for firms above AS 15 000 assessment basis	483.50	553.50	695.50	833.50
	7	SEVERANCE PAY RESERVE PART 1	2.0462 % 2 % of gross wage up to 20 years work credit 3 % of gross wage starting at 20 years work credit	197.87	226.52	283.81	347.11
	8						
LABOUR COSTS PER MONTH	9	CONTINUED WAGE PAYMENTS	0.8 hours per month 0.8 x 82.00 = 65.60 AS/month	65.60			
	10	HOLIDAY PAY	14 paid holidays of 8 hours/year (14 x 8.00 x 82.00) 1/12 = 765.34 AS/month	765.34			
	11	LEAVE PAY	62 workers at 20 days. 3 workers at 25 d/year (62 x 20 x 8.0 x 3 x 25 x 8.0) x 12.00 x 1/65 x 1/12 = 1 105.95 AS/m	1 105.95			
	12	SICKNESS AND ACCIDENT PAY	9.0 hours/month 9 x 82.00 x 0.9 = 664.20 AS/month	664.20			
	13	LEAVE BONUS	the 170 fold of 120 % of time wage/year (170 x 46.00 x 1.2) 1/12 = 782.00 AS/month	782.00			
	14	CHRISTMAS BONUS	the 170 fold of 120 % of time wage/year (170 x 46.00 x 1.2) 1/12 = 782.00 AS/month	782.00			
	15	CHRISTMAS BONUS FOR CHILDREN	the 7 fold of 120 % of time wage/child/year (1.6 x 7 x 46.00 x 1.2) 1/12 = 51.52 AS/month	51.52			
	16	HOUSING PAY	10.00 AS per month 1 x 10.00 = 10.00 AS/month	10.00			
	17	CHILDREN'S ALLOWANCE	44.00 AS per child/month 1 x 44.00 = 44.00 AS/month	44.00			
	18	FIREWOOD BONUS	17 m <sup>3</sup> solid firewood/year (17 x 2.22 x 55.0) 1/12 = 172.98 AS/month	172.98			
	19	HOUSING ALLOWANCE	30.00 AS per month 1.0 x 30.00 = 30.00 AS/month	30.00			
	20	BAD WEATHER PAY	1.1 hours of time wage/month 1.1 x 46.00 = 50.60 AS/month	50.60			
	21	TRAVELLING TIME ALLOWANCE	0.4 hours of time wage/month 0.4 x 46.00 = 18.40 AS/month	18.40			
	22	SEVERANCE PAY PART 2	2.0462 % of 9, 10, 11, 12, 13, 14, 18, 20, 21 4407.07 x 1/100 x 2.0462 = 90.18 AS/month	90.18			
	23	EMPLOYER'S SHARE OF BONUSES		367.99			
INCIDENTAL LABOUR COSTS PER MONTH in AS			- 7.15	7 296.7	7 624.3	8 276.16	8 802.46
LABOUR AND INCIDENTAL LABOUR COSTS PER MONTH in AS			14 296.75	16 024.3	19 476.16	22 802.46	
WORKING WAGE PER HOUR in AS			50	60	80	100	
LABOUR AND INCIDENTAL LABOUR COSTS PER NORMAL WORK HOUR in AS			103.09	115.43	140.06	163.82	
INCIDENTAL LABOUR COSTS IN PER CENT OF PERFORMANCE WAGE (GROSS WAGE PER HOUR)			106.18	92.80	75.08	63.82	

Fig. 3 EXAMPLE OF A TABLE FOR CALCULATING INCIDENTAL LABOUR COSTS (YEAR 1979)

### 3.3 Ascertaining costs per machine hour

The machine is at the centre of most logging systems and operations. Cost per machine hour is therefore an important factor in cost accounting.

Some time ago FAO recommended a system of machine cost accounting which was generally accepted in the Federal Republic of Germany as the FAO/KWF system<sup>1/</sup>. In 1978, a new system based on the old principles was elaborated by the KWF (Leinert 1978). Flachberger developed a similar system for application in a building and machine centre. Fig. 4 shows an attempt to combine the basic ideas of the two accounting models.

C o s t precalculation Period 1979		Machine:        wheeled skidder model 667/2, 139 hp, construction year 1974			No. of cost centre 913/2	
Reference quantity: machine operation hour		Amount: 1 450 hours				
Acc. no.	Cost elements	Unit	Amount	Price AS/unit	Cost in AS/year	
	Items and classification					
1.	<b>WAGE COSTS</b>					
	operators' wages	hrs.	1 450	80.00	116 000	
	incidental labour costs					
	normal inc. lab. costs	hrs.	1 450	60.06	87 087	
	special bonus (30% remote oper.)					
	separation pay	days	43	46.00	1 978	
	accommodation pay	days	43	65.00	2 795	
	work clothes					
	bad weather protection	piece	2	440.00	880	
	gloves	piece	8	31.00	248	208 988
2.	<b>FUELS AND LUBRICANTS</b>					
	<b>fuels</b>					
	diesel oil	1	1 450 x 9.0	7.00	91 350	
	<b>coolants and lubricants</b>					
	engine oil	1	1 450 x 0.18	7.43	1 939	
	gear oil	1	1 450 x 0.07	19.74	2 004	
	hydraulics oil	1	1 450 x 0.087	7.00	883	
	others	1	1 450 x 0.10	20.70	3 002	
	grease	kg	1 450 x 0.028	12.50	508	
	antifreeze	1	1 450 x 0.035	17.00	814	100 500

(continued)

<sup>1/</sup> KWF = Kuratorium für Waldarbeit u. Forsttechnik

3.	WEAR PARTS					
	tyres	piece	1.4	16 335.00	22 869	
	tubes	piece	1.5	951.00	1 427	
	chains	piece	1.7	10 431.00	17 733	
	steel cables	piece	1 450 x 0.37	24.38	13 080	
	chokers	piece	1 450 x 0.18	150.00	39 150	
	cable components	piece	1 450 x 0.015	200.00	4 350	
	filter	(hrs.)	1 450	3.80	5 510	
	miscellaneous	(hrs.)	1 450	2.50	3 625	107 744
4.	REPAIR AND MAINTENANCE					
	repair by service shops	(hrs.)	1 450	7.00	10 150	
	internal maintenance					
	mechanics' wages	hrs.	220	125.80	27 676	
	helpers' wages	hrs.	220	113.42	24 952	
	special bonus	days	8	111.00	888	
	(30% remote oper.)					
	spare parts	(hrs.)	1 450	40.25	58 362	
	tools				600	
	internal service shop costs	hrs.	220	120.00	26 400	149 028
5.	DEPRECIATION, INTEREST, TAXES, INSURANCE, GARAGE					
	depreciation	hrs.	1 450	76.36	110 722	
	interest (8%)	AS	420 000	0.08	33 600	
	taxes	.	-	-	-	
	insurance	.	1	360.00	360	144 682
TOTAL COSTS 1979					710 942	
	Cost rates per hour in AS	1 wage	2 - 4 oper.	5 dep.+ins.	total	mach. with- out oper.
		144	246	100	490	346

Fig. 4 EXAMPLE OF MACHINE COST PRECALCULATION

The machine hour used here is the productive operating time and it includes interruptions of less than 15 minutes. Where the productive operating hours cannot be determined, running time of the engine may be chosen as a basis for costing. Failing this, work hours of the operator may be used.

### 3.3.1 Cost elements

For machine cost accounting it is advisable to group cost elements as follows:

(1) wage costs, (2) fuels and lubricants, (3) wear parts, (4) repair and maintenance, and (5) depreciation, interest, taxes, insurance, garage.

- (1) Wage costs include all paid time of the operator and helpers (including incidental labour costs) but do not include time for repair and maintenance.
- (2) Cost of fuels and lubricants is based on experience data and on data supplied by manufacturers.

- (3) Wear parts are those parts which normally have a shorter life than the machine as a whole and consequently must be replaced one or more times during the life of the machine. Examples include tyres, tubes, filters, chains, cables and chokers. The costs of wear parts are estimated from the useful life of each part.
- (4) Repair and maintenance costs are interdependent and so are considered together in cost accounting. This element includes outside services as well as internal shop costs, labour costs for time spent on maintenance by operators and helpers, labour costs for mechanics and other shop employees, tools, and spare parts. For precalculation, repair costs are based on experience or, if experience values are not available, are related to depreciation. The latter estimates must be amended as experience values become available.
- (5) The final group covers costs which are more or less time-related and, consequently, are fixed. Costs of this nature include interest, taxes, insurance and garage. Depreciation, however, is not only time-related but is also performance-related.

Note: Figures in parentheses are guide values since underlying data are insufficient for judgement.						
	normal asset life (H)	obsolescence (N)	utilization limit (H:N)	repair cost coefficient in relation to depreciation	fuel consumption	lubricant costs in % of fuel consumption
Machine groups	MOH*	years	MOH/year		1/MOH	%
1. Wheeled skidders						
1.1 Forest skidders						
up to 30 kW	5 000	6.0	830	1.2	2.0	10
31 - 45 kW	7 000	6.0	1 170	1.2	3.0	10
above 45 kW	8 000	6.0	1 330	1.2	4.0	10
1.2 Special skidders						
30 - 50 kW	7 000	6.0	1 170	1.1	3.0	15
above 50 kW	9 000	7.0	1 280	1.1	4.0	15
1.3 Grapple yarders	(8 000)	(6.0)	(1 330)	(1.1)	(4.0)	(15)
1.4 Forwarders	(8 000)	(6.0)	(1 330)	(1.0)	(8.0)	(20)
2. Other logging machines						
2.1 Mobile debarkers	7 500	5.0	1 500	1.1	20.0	35
2.2 Delimbers + debarkers						
ETE 100	(6 000)	(6.0)	(1 000)	(1.2)	(2.0)	(15)
Astab 250 A	(6 000)	(6.0)	(1 000)	(1.2)	(2.0)	(15)
2.3 Skidding bogie + crane	(5 000)	(6.0)	(1 000)	(1.2)	(2.0)	(15)
3. Road construction machines						
3.1 Lorries	10 000	8.0	1 230	0.8	10.0	5

\* MOH = Machine Operating Hours

Fig. 5 BASIC DATA FOR CALCULATING MACHINE COSTS

(Source: Kuratorium für Waldarbeit, Fed. Rep. of Germany, Leinert).



### 3.3.2 Computing depreciation

Depreciation is the loss in value of an asset through wear, tear and obsolescence over a period of time. In accounting terms, depreciation is the distribution of the acquisition value of an asset over its useful life. Correct accounting for depreciation should ensure that the full acquisition cost of the machine is recovered during the depreciation period.

The important elements for computing depreciation include the total amount to be depreciated, the depreciation period, and the depreciation method.

#### i) Total depreciation amount

The total depreciation amount is the sum of all depreciation charged during the life of the asset. It may be based on the all-inclusive purchase value or, if the machine is manufactured within the enterprise, on the total production cost. In either case, the residual or scrap value must be deducted from the acquisition cost. In precalculation of depreciation, a zero residual value is often assumed but actual re-sale value should be used in final calculations.

In periods of inflation, the machine cost may increase with time so that depreciation calculated on acquisition cost does not truly reflect the asset value. In such cases replacement value reflecting inflation should be used instead of acquisition cost and depreciation should be recalculated each year.

#### ii) Depreciation period

The depreciation period is an estimate of the useful life of an asset. The accuracy of this estimate is very important in cost accounting. If the estimate is too long, depreciation will be too low and the asset will require replacement before it is fully depreciated; if it is too short, initial depreciation charges will be too high. In either case, the costs derived from these estimates will be inaccurate.

An accurate estimate of the useful life of a new machine may be rather difficult to make. Repair and maintenance costs increase with the age of a machine and these costs must be considered in determining the useful life. It is a generally accepted rule that a machine should be replaced as soon as the running costs per performance hour equal or exceed those for a new machine. The experience data shown in Fig. 5 have been found invaluable in making estimates of useful machine life.

Asset life is measured either by utilization or by obsolescence, depending on the annual hours of operation. Fig. 5 shows the utilization limit (H:N) in machine hours per year; beyond this limit depreciation should be determined from obsolescence. Technological innovations may seriously affect the useful life of a machine by introducing alternatives with superior performance. In such cases, the depreciation period must be reduced and depreciation recalculated.

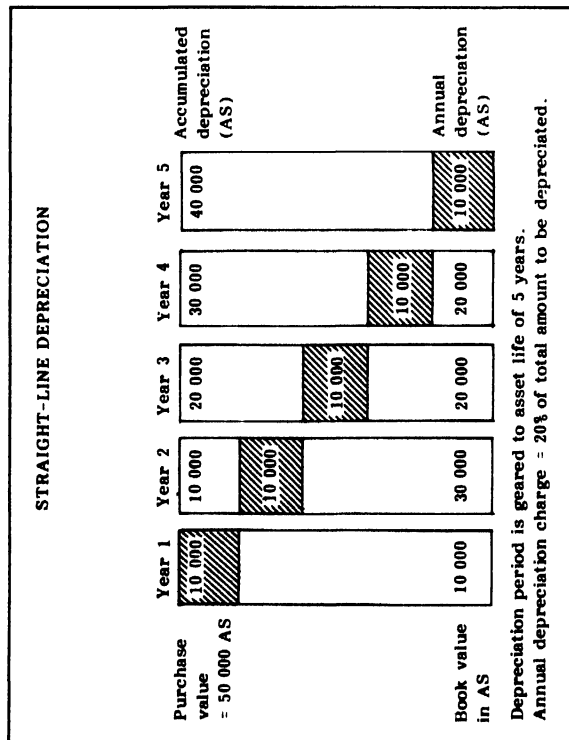
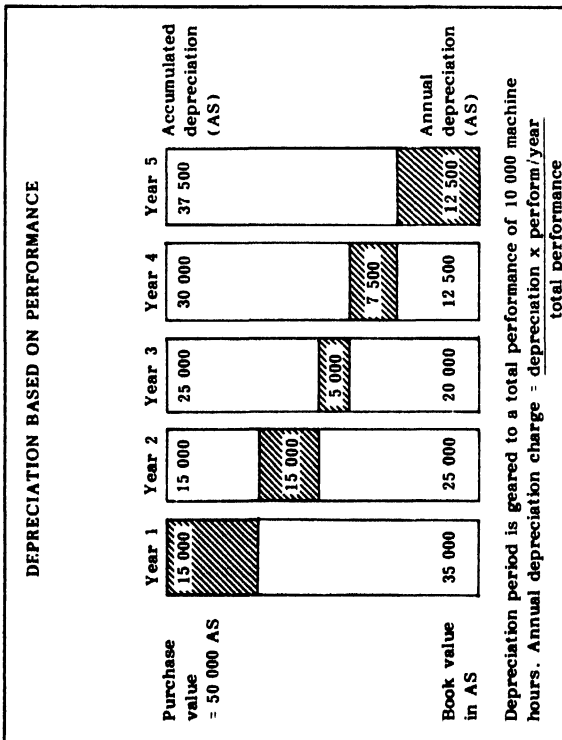
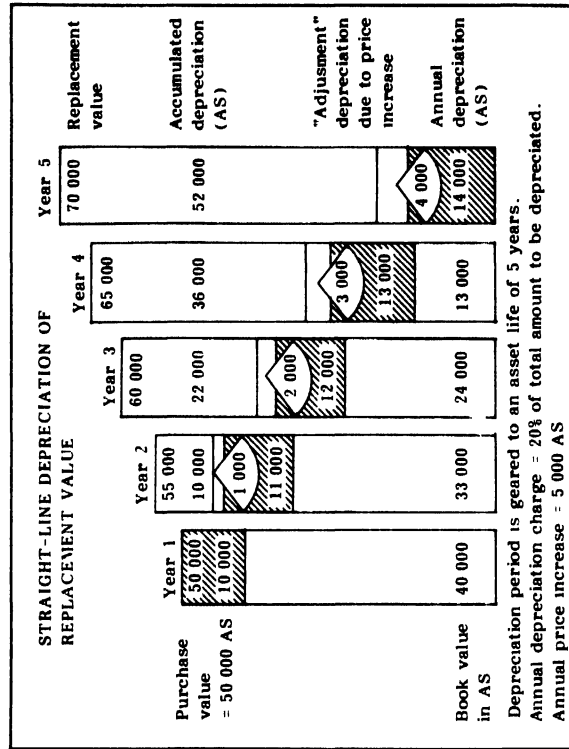
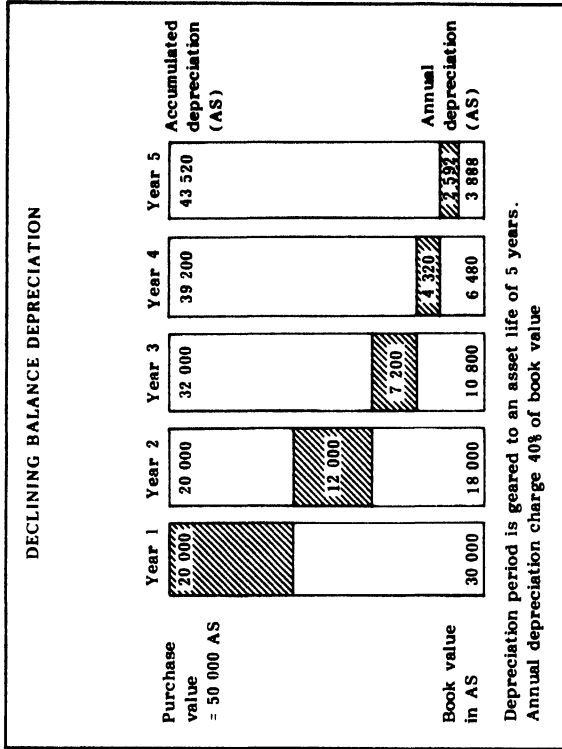


Fig. 6 METHODS OF CALCULATING DEPRECIATION

### iii) Depreciation methods

Although specialized methods are used in financial accounting for taxation purposes, there are only three basic methods for calculating depreciation for machine costing

- allocation by performance
- straight line
- declining balance

Each method will yield a different annual depreciation amount. (Fig. 6)

#### a) Depreciation based on performance

When depreciation is based on performance, machine life is considered to be a fixed number of operating hours rather than a period of calendar time. The depreciation costs per hour are calculated by dividing the purchase price by the total operating hours. However, if the machine is likely to become obsolete within a fixed period of years, the estimate of total operating hours must not exceed the expected operating hours within that period of years.

Depreciation based on performance is the only theoretically correct method for use in machine cost accounting.

#### b) Straight-line depreciation

The straight-line method of allocation divides the total amount to be depreciated into equal annual amounts over the life of an asset. The method is simple to apply but it is not accurate for machinery unless the machine is used for the same operating hours each year and is equally effective throughout its life. This is most unlikely as under most conditions of operation, the value decreases and the need for repairs increases as the machine ages.

#### c) Declining balance depreciation

In declining balance accounting annual depreciation is a fixed percentage of the book value of an asset so that the annual depreciation charges are much higher in the early years than they are in subsequent years. That is, depreciation charges are high when repair costs are low but become lower as the need for repairs increases. Under the declining balance method an asset can never be fully depreciated. Consequently, the straight-line method is used toward the end of the asset's life.

### 3.3.3 Imputed interest and interest rates

Interest charges are those costs which are incurred in employing funds, both owned and borrowed, to operate an enterprise. In cost accounting for machines, interest costs are based on the undepreciated balance of the cost or residual value of the machine.

Imputed interest rates are determined by the general conditions in the capital market. For borrowed funds, the minimum rate to be used is the actual rate on the loan plus all incidental charges; for internal capital, the minimum rate is the rate necessary to maintain the asset value in the face of inflation.

Over the life of an asset, the undepreciated value will average one-half of the initial cost. To simplify calculations, it is common practice to use this average value as the base for interest calculations. For example, in Fig. 4 annual interest charges were calculated as  $8\% \text{ of } 840\,000/2 = 33\,600 \text{ AS}$ .

#### 3.3.4 Prime costs

In cost accounting both total annual costs and costs per hour are kept separately by the components shown in Figure 4. This is most important when it becomes necessary to reflect changes in one or more of the components. Separation of fixed and variable components is necessary for planning changes in annual usage and for the control of planned costs. Separate costing of machine work with and without operator is important for operational precalculation and recalculation.

From the above data and from performance data for the machine, the prime costs per performance unit are determined.

#### 3.4 Project, operation or contract accounting

For each logging project, all elements, both machines and workers, are combined into a logging system and the individual phases of the operations are carefully planned and estimated.

Precalculations serve the dual purpose of determining price and controlling the efficiency of the project.

Precalculation requires data on the prime costs for individual production units; exact knowledge of the site factors which influence cost and performance such as timber species, diameters, terrain, logging distance, etc., and performance figures as well as time requirements of individual elements with regard to the above site factors. Site factors are determined by field study. Time requirements are estimated from experience, time studies and reports of comparable logging operations.

Fig. 7 shows the results of a logging operation and recalculation. For such accounting the basic data must be collected regularly and accurately; the accounting sheets must be well arranged; and the sheets must be appropriately delivered for analysis. The type of performance, work hours, machine hours, other time requirements, special costs and fuel and oil consumption must be continuously recorded and finally summed up in the sheet. Entries are made for quantity units, prime costs, and direct expenses. Total sums show overall costs of work phases and cost elements. Dividing these factors by performance units equals  $\text{cost/m}^3$  (performance units). Actual costs are compared with the planned precalculated costs and differences are explained by causal analysis.

COST SHEET FOR A LOGGING PROJECT Site: M.N. Operation period: 6 March to 3 April 1979  
 Key: Hx Number of days: 16,5

Cost Centre	Wages, salaries incl. labour costs		Machine and devices				consumption of goods contracts	Other costs				Special costs (per diem + travel expenses)				Total costs		c/m <sup>3</sup>
	units	AS/ unit	Name	Units	AS/ unit	Amount		Name	Units	AS/ unit	Amount	Name	Units	AS/ unit	Amount	Total Amount	Σ	
Planning																		
			flat-bed tractor	25.5	415.00	10,582.50												
			truck	35.5	254.00	9,017.00						p.d.	169.5	6.00	1,017.00			
	169.5	102.80	skidder	28.5	327.00	9,319.50										49,065.10	3.5	
		17,424.60	wheeled loader	6.5	213.00	1,384.50											8.30	
		pick-up	80.0	4.00	320.00													
Felling	672.5	120.76	power-saw	592.0	33.00	19,536.00												
		81,211.10	skidder	1,137.0	327.00	371,799.00						p.d.	672.5	6.00	4,035.00	104,767.05	7.4	
Skidding	1,915.0	120.07	cable winch	156.0	324.00	50,544.00												
		229,934.05										p.d.	1,915.0	6.00	11,490.00	363,767.05	47.5	
Transport to landing																		
Landing	661.5	119.41	harvester	141.5	1,237.0	175,035.20												
		78,989.72	wheeled loader	302.5	213.00	64,432.50						p.d.	661.5	6.00	3,969.00	326,424.22	23.2	
			skidder	6.5	327.00	2,125.50												
			power-saw	156.0	12.00	1,872.00												
			truck	164.0	254.00	41,656.00						p.d.	164.5	6.00	987.00	61,127.87	4.3	
Transport to consumer	164.5	112.57															10.33	
Miscellaneous work	20.5	111.59	skidder	2.0	327.00	654.00												
		2,287.60	wheeled loader	9.5	213.00	2,023.50						p.d.	20.5	6.00	123.00	5,088.30	0.4	
Worker's transport	212.5	86.25	bus km	10,814	4.00	43,256.00												
Miscellaneous transport			car km	92	2.40	220.80												
			pick-up km	393	4.00	1,572.00						p.d.	212.5	6.00	1,275.00	63,278.88	4.5	
																	10.70	
																	0.30	
Head of timber Processing unit	16.5	5,100.0	car km	2,383	2.40	5,719.20												
Construction of machine yard	16.5	2,007.0	car	16.5	161.00	2,656.50												
		34,270.50	office	16.5	414.00	6,831.00												
																	15.19	
																	7.90	
PRIME COSTS	95.60	AS/m <sup>3</sup>		137.56	AS/m <sup>3</sup>	813,726.00						1.15	AS/m <sup>3</sup>		6,831.00	22,896.00	100.0	
		40.1%				57.8%											238.25	

<b>1. RESULT</b>				
timber quantity	5 915.31	m <sup>3</sup>	7 185	stems
earnings	1 417 982.19	AS	240.00	AS/m <sup>3</sup>
costs	1 409 302.92	AS	238.25	AS/m <sup>3</sup>
profit	8 673.27	AS	1.75	AS/m <sup>3</sup>
loss		AS		AS/m <sup>3</sup>
<b>2. KEY FACTORS</b>				
Work productivity	1.64	m <sup>3</sup> /h	2.0	piece/h
felling	9.99	m <sup>3</sup> /h	12.1	piece/h
skidder	5.20	m <sup>3</sup> /h	6.3	piece/h
ground winch	10.06	m <sup>3</sup> /h	8.3	piece/h
cable crane		m <sup>3</sup> /h		piece/h
truck (transport to landing)		m <sup>3</sup> /h		piece/h
truck (transport to consumer)	36.07	m <sup>3</sup> /h		piece/h
wheeled skidder	39.11	m <sup>3</sup> /h		piece/h
harvester	41.80	m <sup>3</sup> /h	50.8	piece/h
Efficiency of harvester			0.88	of norm. oper. time
Work hour costs				
(incl. incid. labour costs, transport of workers and special costs)			142.49	AS/work hour
mobilization			126.37	AS/work hour
felling			177.33	AS/work hour
skidding			143.64	AS/work hour
transport to landing + consumer			135.94	AS/work hour
work at landing			142.98	AS/work hour
Transport of workers and special costs			14.35	AS/m <sup>3</sup>
Wage and salary costs			40.1	% of total c.
Average gross earning			66.70	AS/work hour
Special costs			6.00	AS/work hour
<b>3. SITE FACTORS</b>				
Type of timber	mean diameter	24.6	cm	
(96 % spruce, 4 % larch)	mean stem content	0.82	m <sup>3</sup>	
	mean stem length	17.5	m	
Site	number of operation sites	27		
	mean skidding distance 0/270,	974	m	
	mean access distance	-	m	
	machine transport distance	35	km	
	distance from firm's headquarters	36	km	
Terrain	slope	50	%	
	soil soft due to melting snow			
	snow cover	40-50	cm	
Landing	area	2 500	m <sup>2</sup>	
Climate	heavy snowfall, thawing			
	4.5 days of bad weather			
Cable transport percentage	ground cable winch	26.5	%	
	cable crane 3.9 % with 2 skidders		%	

Fig. 8 RESULTS. KEY FACTORS AND SITE FACTORS OF LOGGING OPERATION (see to Fig. 7)

Recalculated results show the key factors (Fig. 8) which are used for cost control and causal analysis as well as for planning and control of subsequent operations.

Determination of the costs of long-term consequences of individual operations or logging systems from an economist's point of view requires knowledge of specific opportunity costs. Long-term consequences include, for example, the loss of value resulting from damage to stand and soil. This damage will not be reflected financially for many years to come. Knowledge of opportunity costs is particularly important if such damage can be avoided or reduced by alternative methods of logging or by better planning or more careful work.

### 3.5 Periodic review

For management purposes a periodic report of logging accounts is prepared. Costs and performances are determined for each piece of equipment and for each cost centre. Costs and related data such as use capacity, fuel price, etc., are continuously checked for accuracy. If actual capacity differs from the estimated value, the prime costs must be changed so that the sum of the costs of individual phases balances with the overall costs of the enterprise. After all, an independent logging department has its own objectives for profit, cost coverage, cash and capital, and these should be reached.

## 4. CONCLUSIONS

Cost accounting in logging has become essential for price determination: for supervision and control of present logging activities; for detection of areas in which cost reduction is most likely to be feasible and important; and for comparison of new methods with present practices. Supervision and analysis of complex systems of logging in which high economic values are involved will commonly require complex and sophisticated analytical methods and computing equipment. On the other hand much useful analysis of logging costs can be performed on a modest scale especially a systematic review of regular operating costs and productivity, based on data developed as part of normal accounting and management procedures.

Overall accounting requires clear objectives, useful equipment and integration, appropriate flow of accounts and data, and efficient methods of data collection and processing. Finally, knowledge of cost-influencing factors as well as continuous comparison between planned (standard) and actual results are further requisites of modern management-oriented cost accounting.

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Portable winch being used to haul into place  
the Leykam Log-Line plastic chutes used in  
the gravity transport of timber



## LOGGING CASE STUDIES

by

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### UPHILL AND DOWNHILL LOGGING BY SLEDGE WINCH OF CONIFEROUS ROUNDWOOD FROM THINNINGS

#### Uphill logging

##### Location

Ossiach District

Stand aged 55 years, 100% spruce, growing stock 0.7, slope gradient 60 to 70%, aspect northwest, timber output 30.0 m<sup>3</sup>. Mean diameter of harvested trees 15 cm, logging distance 20 to 60 m.

##### Planning and organization

Staking of skidding track and harvesting width, marking of trees to be harvested, determining anchor trees for winch; two assortments, construction timber and pulpwood, are produced.

##### Working method

The marked trees were felled on to the skidding track and processed into assortments. The logs were bundled into maximum loads of 0.5 m<sup>3</sup>, individual bundles were stored on supports to leave some space underneath for chokers to be set; the prepared bundles were skidded to the forest road by sledge winch. Three workers were required: one winch operator, one worker at the mainline and one worker to sort and stock the timber. Workers replaced one another to avoid monotony.

##### Operations

Pulling cable to load	20.35 minutes	=	21%
Attaching load	22.35 minutes	=	23%
Loaded travel	31.25 minutes	=	33%
Detaching, assorting and storing timber	13.00 minutes	=	14%
Delay due to work conditions and breaks	8.50 minutes	=	9%
Total work time	95.45 minutes	=	100%
For 3 workers	286.35 minutes		

Number of trips	28
Volume skidded in 95.45 min.	5.74 m <sup>3</sup>
Mean diameter	15 cm
Average load volume	0.21 m <sup>3</sup>
Average number of logs per load	3
Time required for one complete work sequence	3.41 min.
For 3 workers	10.23 min.
Output per hour	3.61 m <sup>3</sup>
Daily output for 3 workers and 8 working hours	28.88 m <sup>3</sup>

#### Costs

Machine costs per operating hour	AS <sup>1/</sup> 70.-
Worker costs per hour	AS 53.-
Addition for social welfare 100%	AS 53.-
Machine 4.32 hours x 70.-	AS 302.-
3 workers x 8 hours x 106.-	AS 2 544.-
Total	AS 2 846.-
Total costs per m <sup>3</sup> (AS 2 846 ÷ 28.88 m <sup>3</sup> )	AS 98.56 (US\$ 5.80)
Utilization of machine capacity	54%

#### General remarks

This case was a short time study to get an overall view. If work continued over a longer period, the share of breaks would definitely increase (break allowance for work in Austrian mountainous areas amounts to 20%) thereby reducing the productivity rate by some 10%.

#### Downhill skidding

#### Location

Ossiach District

Stand aged 35 years, 100% spruce, growing stock 0.7, maximum slope 15%, aspect northwest, average diameter of harvested stems 14 cm; skidding distance 22 m.

1/ AS = Austrian Schilling. 1 US\$ = 17 AS

## Planning and organization

See uphill skidding

## Working method

See uphill skidding

## Operations

Pulling cable to load	37 min.	-	30.8%
Attaching load	17 min.	=	14.2%
Loaded travel	34 min.	=	28.3%
Detaching load	12 min.	=	10.0%
Delay due to work and breaks	20 min.	=	16.7%
Total work time	120 min.	=	100%
For 3 workers	360 min.		
Number of trips	48		
Volume skidded in 120 min.	12.26 m <sup>3</sup>		
Mean diameter	14 cm		
Average load volume	0.255 m <sup>3</sup>		
Average number of logs per load	4 logs		
Time required for one complete work sequence	2.5 min.		
For 3 workers	7.5 min.		
Output per hour	6.13 m <sup>3</sup>		
Daily output, 3 workers for 8 working hours	49.04 m <sup>3</sup>		

## Costs

Machine costs (sledge winch) per operating hour	AS 70.-	
Working costs per hour	AS 53.-	
Addition for social welfare 100%	AS 53.-	
Machine 4.73 hours x 70.-	AS 331.33	
3 workers x 8 hours x 106.-	AS 2 544.-	
Total	AS 2 875.33	
Total costs per m <sup>3</sup> (2 875 + 49)	AS 58.63	(US\$ 3.45)
Utilization of machine capacity	59.13%	

General remarks

The terrain was relatively flat and the skidding distance of 22 m was short, making work conditions in this case very favourable.

# UPHILL LOGGING OF CONIFEROUS ROUNDWOOD BY CABLE CRANE ON A CLEARCUT AREA

(Data collation by Karl Katholnig)

### Location

## Ossiacher Tauern

Stand aged 90 years, 100% spruce, growing stock 0.7, slope about 70%, aspect northwest, timber output 123.32 m<sup>3</sup> inside bark. Crosscutting into logs 4 m long, average diameter 18 cm, maximum skidding distance 165 m.

## Planning and organization

Staking of cable corridors and harvesting width of 30 m, lateral skidding distance therefore 15 m, marking of anchor trees on the mountain and in the valley, choosing trees for supports.

## Working method

The area to be clearcut was marked, trees were felled toward the nearest cable corridor and harvested according to the assortment method. Branches were piled in heaps and logs stacked in bundles. When felling was completed, the cable crane was mounted. A 16-hp Nesler cable winch and a light carriage with hoisting winch were used. Supports were made of prefabricated parts. (Both components of the cable crane system are special developments of the Forestry Training Centre, Ossiach.) Logs were stored ready for sale on the forest road. The working team consisted of one winch operator and one or two forest workers.

## Operations

## Working team and working phases

Mounting corridor I		3 workers
Cable-logging corridor I		3 workers
Changing to corridor II		2 workers
Cable-logging corridor II		3 workers
Changing to corridor I		2 workers
Cable-logging corridor I		3 workers
Dismantling of cable system		2 workers
Length of skyline		165 m
Logging distance		150 m
Timber output: corridor I	95.77 m <sup>3</sup>	under bark
corridor II	27.55 m <sup>3</sup>	under bark
Total output	123.32 m <sup>3</sup>	under bark
Average solid content and diameter per piece	0.10 m <sup>3</sup>	and 18 cm

<u>Mounting corridor I (3 workers)</u>	<u>min.</u>	<u>%</u>
Unloading of material	13	7.3
Positioning of winch	15	8.5
Setting up mountain anchor for skyline	8	4.5
Pulling out skyline	12	6.8
Preparing valley anchor and endmast	7	4.0
Erecting endmast	3	1.7
Erecting support I	11	6.2
Erecting support II	10	5.6
Erecting support III	10	5.6
Pulling out mainline	3	1.7
Mounting carriage and stopping device	6	3.4
Mounting grapple tensioner and mainline pulley	7	4.0
Clearcutting corridor	36	20.3
Tensioning skyline	7	4.0
Walking allowance	4	2.2
Delay due to work conditions	7	4.0
Breaks	18	10.2
Total time	177	100%
Time per worker	59 min.	

#### Cable logging corridor I

Working time and breaks	727 min.
Machine time	655 min.
Logging volume	87.63 m <sup>3</sup>
Logging output in pieces	832 logs
Maximum lateral logging distance	15 m
Number of trips	294
Working time per trip	2.23 min.
Load per trip	0.30 m <sup>3</sup> or 2.8 logs
Work performance	0.13 hours/m <sup>3</sup> (= about 8 min.)

Change to corridor II (2 workers)

Corridor II 10 m away		
Slackening skyline	2	1.6
Dismantling valley anchor and endmast	3	2.3
Rewinding skyline and pulling it out on corridor II	15	11.7
Changing over and setting up endmast	5	3.9
Support I dismantling, changing over, setting up	13	10.2
Support II - ditto -	14	10.9
Support III - ditto -	19	14.8
Changing over and mounting stopping device	5	3.9
Changing over and mounting carriage	4	3.1
Setting up mountain anchor	5	3.9
Positioning winch	4	3.1
Setting up grapple tensioner	2	1.6
Pulling out mainline and mounting block	3	2.3
Tensioning skyline	7	5.6
Walking allowance	8	6.3
Delay due to work conditions	5	3.9
Breaks	14	10.9
Total time	128	100%
Time per worker	64 min.	

Cable logging corridor II

Working time and breaks	279 min.	
Machine time	251 min.	
Logging volume	27.55 m <sup>3</sup>	
Logging output in pieces	315 logs	
Maximum lateral logging distance	10 m.	
Number of trips	104	
Working time per trip	2.41 min.	
Load per trip	0.27 m <sup>3</sup>	(about 3 logs)
Work performance	0.15 h/m <sup>3</sup>	(about 9 min.)

<u>Change to corridor I</u> (2 workers)	<u>min.</u>	<u>%</u>
Slackening skyline	3	2.4
Dismantling valley anchor and endmast	4	3.2
Rewinding skyline and pulling it out on corridor I	18	14.5
Changing over and mounting endmast	5	4.0
Support I dismantling, changing over and mounting	16	12.9
Support II - ditto -	12	9.7
Support III - ditto -	12	9.7
Changing over and mounting stopping device	5	4.0
Changing over and mounting carriage	6	4.8
Setting up mountain anchor	3	2.4
Positioning winch	2	1.6
Pulling out mainline and mounting block	5	4.0
Tensioning skyline	7	5.7
Walking allowance	7	5.7
Delay due to work conditions	5	4.0
Breaks	14	11.4
Total time	124	100%
Time per worker	62 min.	

#### Cable logging corridor I

Working time and breaks	80 min.
Machine time	72 min.
Logging volume	8.14 m <sup>3</sup>
Logging output in pieces	92 logs
Maximum lateral logging distance	15 m
Number of trips	29
Working time per trip	2.48 min.
Load per trip	0.28 m <sup>3</sup> (about 3 logs)
Work performance	6.78 m <sup>3</sup> /h
	0.15 h/m <sup>3</sup> (about 9 min.)

<u>Dismantling cable crane</u> (2 workers)	<u>min.</u>	<u>%</u>
Slackening skyline	3	4.2
Dismantling valley anchor and endmast	2	2.8
Rewinding mainline and dismantling mainline block	2	2.8
Rewinding skyline	4	5.6
Dismantling endmast	2	2.8
Support I dismantling and carrying up	5	6.9
Support II - ditto -	7	9.7
Support III - ditto -	9	12.5
Dismantling carriage and stopping device	2	2.8
Dismantling mountain anchor	1	1.4
Detaching and loading grapple tensioner	2	2.8
Dismantling winch	3	4.2
Loading winch	14	19.4
Walking allowance	3	4.2
Breaks	8	11.1
Total time	72	100%
Time per worker	36 min.	

Summary of mounting and logging times

Mounting corridor I	59 min. x 3 workers = 177 min.	
Logging corridor I	727 min. x 3 workers = 2181 min.	
Changing over to corridor II	64 min. x 2 workers = 128 min.	
Logging corridor II	279 min. x 3 workers = 837 min.	
Changing over to corridor I	62 min. x 2 workers = 124 min.	
Logging corridor I	184 min. x 3 workers = 552 min.	
Dismantling cable device	36 min. x 2 workers = 72 min.	
Total	1 411 min.	4 071 min.
	23.52 hours	67.85 hours
Machine times: corridor I	655 + 72 = 727 min.	
corridor II	251 min.	
Total	978 min.	= 16.3 hours



<u>Costs</u>	<u>AS</u>
Machine costs per operating hour	110.-
Winch driver, costs per working hour including social welfare (100%)	118.-
Forest worker, costs per working hour including social welfare (100%)	106.-
Total machine costs 16.30 hours x AS 110.-	1 793.-
Total winch driver costs 23.52 hours x AS 118.-	2 775.36
First forest worker 23.52 hours x AS 106.-	2 493.12
Second forest worker 20.82 hours x AS 106.-	2 206.92
Total	9 268.40 (US\$ 545)

### Cost distribution/m<sup>3</sup>

Machine	14.54
Winch driver	22.51
First forest worker	20.22
Second forest worker	17.90
Total	75.17 (US\$ 4.42)

Utilization of cable crane capacity 24%

### General remarks

Cable-logging is very labour intensive. In the present case costs for the machine were 20% and costs for the working team were 80% of the total. Therefore reducing the number of workers in the team should be considered. In countries with low wages bigger teams will yield more economic results.

DOWNHILL SKIDDING OF CONIFEROUS ROUNDWOOD BY ARTICULATED WHEELED SKIDDER KOCKUM 821, EQUIPPED WITH DOUBLE-DRUM WINCH (Data collation by Friedrich Singer)

### Location

Ossiach District

Sixty-year-old spruce stand, mean annual increment 0.8 m<sup>3</sup>; slope 40 to 60%, aspect northwest; harvested trees derived from a snowbreak and thinnings; maximum tree height 26 m; mean diameter 17 cm.

### Planning and organization

Skidding tracks 100 to 200 m long were laid out almost exclusively for downhill transport. Skidder could not always travel directly up the track. The full-length method was used.

### Working method

Trees on skidding tracks were felled and delimbed. Stumps were cut even with the ground. Trees along both sides of skidding track were felled in an acute angle to the track, delimbed and crosscut to 8 m or 12 m where necessary to reduce skidding damage and to avoid breakage of skidded stems. After felling and crosscutting the timber was skidded. The team consisted of three workers: one skidder driver, one choker man, one worker for final delimbing and crosscutting on the forest road.

### Work performance

Felling	0.60 m <sup>3</sup> /hour
Skidding production	6.03 m <sup>3</sup> /hour
Load per trip	2.33 m <sup>3</sup>
Working time of skidder	17 hours
Working time of skidder driver	20 hours
Working time of 2 workers, each	20 hours
Number of trips	44
Volume of skidded timber	102.42 m <sup>3</sup>

### Costs

Skidder driver (incl. social welfare 100%)	118.-	AS/hour
Forest worker (incl. social welfare 100%)	106.-	AS/hour
Wheeled skidder	350.-	AS/operating hour
Felling costs	63.60	AS/m <sup>3</sup>
Costs of final delimbing and crosscutting	19.74	AS/m <sup>3</sup>
Skidding costs, machine	58.04	AS/m <sup>3</sup>
Skidding costs of driver	23.04	AS/m <sup>3</sup>
Skidding costs of worker	20.70	AS/m <sup>3</sup>
Total sum for felling	83.34	AS/m <sup>3</sup>
Total sum for skidding	101.78	AS/m <sup>3</sup>
Total logging costs	185.12	AS/m <sup>3</sup> (US\$ 10.89/m <sup>3</sup> )
Utilization of machine capacity	85%	

### General remarks

Skidding performance of skidder was very good because skidding distance was relatively short. Total costs comprising felling and skidding were in line with average Austrian costs.

## UPHILL AND DOWNHILL EXTRACTION BY SHORT-DISTANCE CABLE CRANES AND WHOLE-TREE METHOD

### Uphill extraction

#### Location

Hartelsberg District

Stand 3/42, aged 145 years, 100% spruce, mean annual increment  $0.6 \text{ m}^3$ ; slope 70-80%, southwest aspect, harvested timber volume  $709 \text{ m}^3$ , mean diameter 31.3 cm, harvesting method: stand removal in narrow strips.

#### Planning

Surveying and staking cable line, marking trees for cross-cable supports, endmast and anchoring.

#### Working method

Whole trees were logged uphill to the forest road by Urus-Gigant cable crane. Lateral skidding and storage for processing was done by Timberjack 225 D. Two workers were required for felling, removing branches larger than 2 m, removing defective wood and crosscutting large-diameter trees. Uphill logging requires two workers at the felling site and one crane operator. Extraction takes place after felling is finished.

#### Work performance

Felling	$7.50 \text{ m}^3/\text{hour}$
Uphill extraction	$8.60 \text{ m}^3/\text{hour}$
Work with processor	$25.10 \text{ m}^3/\text{hour}$

#### Costs

Felling	$12.10 \text{ AS/m}^3$
Uphill extraction incl. workers	$82.20 \text{ AS/m}^3$
Storing	$25.90 \text{ AS/m}^3$
Delimbing and crosscutting by processor	$42.70 \text{ AS/m}^3$
	$162.90 \text{ AS/m}^3 \text{ (US\$ } 9.58/\text{m}^3 \text{)}$

#### General remarks

This study was carried out on very rocky and difficult terrain. Exact planning, observation of felling direction and a well-trained working team were indispensable for appropriate performance.

## Downhill extraction

### Location

Hinterberg District

Stand 7/29, aged 145 years, 0.9 spruce, 0.1 larch; slope 60-80%, north aspect; timber volume harvested 472 m<sup>3</sup>, mean diameter about 34.2 cm, harvesting method: liberation cutting, natural reforestation on lower slope.

### Planning

Staking cable line, marking trees for cross-cable supports, endmast and anchoring and route of haulback line.

### Working method

Whole trees were transported downhill to the forest road by Urus-Gigant cable crane. Lateral skidding and storage for processing by wheeled skidder.

Two workers were required for felling, removing branches longer than 2 m, removing defective parts and crosscutting large-diameter trees. Downhill logging requires two workers at the felling site and one crane operator. Extraction starts after felling is finished.

### Work performance

Felling	4.10 m <sup>3</sup> /hour
Downhill extraction	9.50 m <sup>3</sup> /hour
Work with processor	27.40 m <sup>3</sup> /hour

### Costs

Felling	22.00 AS/m <sup>3</sup>	
Downhill extraction	84.20 AS/m <sup>3</sup>	
Storing	35.90 AS/m <sup>3</sup>	
Delimbing and crosscutting by processor	38.50 AS/m <sup>3</sup>	
Total	180.60 AS/m <sup>3</sup>	(US\$ 10.62/m <sup>3</sup> )

### General remarks

This study covered downhill and diagonal extraction by Urus-Gigant crane. The lower slope was steep and partly rocky. Storage was easy since a road curve had been chosen for the landing.

## Downhill extraction

### Location

Arling District

Stand 1/56, aged 125 years, 0.9 spruce, 0.1 larch, mean annual increment  $0.8 \text{ m}^3$ ; slope 40–60%, northeast aspect; timber output  $378 \text{ m}^3$ , mean diameter 30.2 cm, harvesting method: stand removal in narrow strips with natural regeneration.

### Planning

Staking cable line, marking trees for cross-cable supports, endmast and anchoring and route of haulback line.

### Working method

See the previous case study.

The forest road being very narrow, the cable line took a slightly diagonal direction to facilitate landing trees.

### Work performance

Felling	$7.00 \text{ m}^3/\text{hour}$
Downhill extraction	$12.20 \text{ m}^3/\text{hour}$
Work with processor	$26.70 \text{ m}^3/\text{hour}$

### Costs

Felling	$13.10 \text{ AS}/\text{m}^3$
Downhill extraction	$72.30 \text{ AS}/\text{m}^3$
Work with processor	$47.30 \text{ AS}/\text{m}^3$
	$132.70 \text{ AS}/\text{m}^3 \quad (\text{US\$ } 7.81/\text{m}^3)$

### General remarks

The terrain was flat; storage was difficult and possible only along the forest road.

### Appendix

Longitudinal profile of cable line

General drawing of terrain with indication of felling direction and storage along forest road.

### Summary

Economic operations require accurate planning. Machinery must be compatible with timber dimensions and terrain. Further prerequisites are: qualified personnel, appropriate safety measures for men and machines, sufficient space on the landing to allow subsequent processor work.



Tractor equipped for forestry work with heavy-duty tyre chains and integrally mounted skidding winch. Note cable mainline and chokers with quick-hitch couplings in foreground  
(Photo: R. Heinrich)

FOREST ECONOMY AND ECOLOGY WITH SPECIAL EMPHASIS  
ON LOGGING IN MOUNTAINOUS AREAS

by

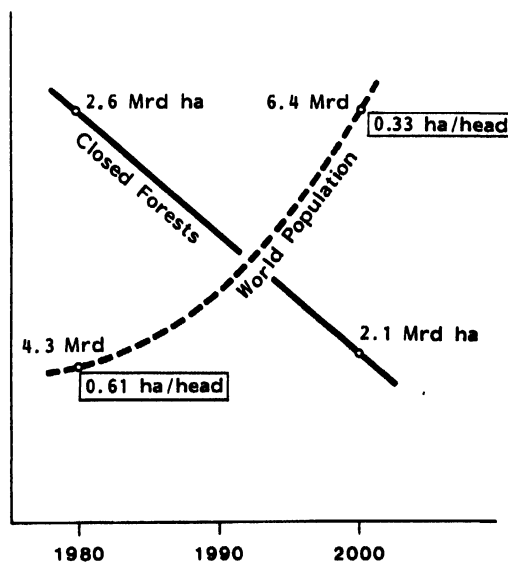
Otto Sedlak

Logging Division  
Forest Service of Upper Austria

For many centuries, man has been blithely destroying the world's forests in order to gain arable land and settlement areas. However, it has been the rapid population growth during the 20th century that has led to a constant shrinkage of the forests. At present, this shrinkage amounts to roughly 15-20 million hectares approximately (38-50 million acres) annually in the tropics alone.

In ecologically sensitive areas, for example, in semi-arid zones or on steep hillsides in the mountains, the time-honoured trend still applies: first came the forests, then man and after him the desert!

WORLD TRENDS  
IN  
POPULATION GROWTH AND  
DESTRUCTION OF FORESTS



Source Global 2000

National forestry policies aim at arresting this development, which threatens life itself on our earth. For all that, however, the pace of forest destruction still amounts to several times the annual reforestation rate. Effective protection of the forests has thus become a problem of international significance.

## THE WORLD'S FORESTS

Closed forests cover about 2 700 million ha (6 750 million acres) of the world's surface. According to a survey conducted by FAO, roughly 1 200 million ha (3 000 million acres) or 44 percent are tropical and subtropical forests, and 1 500 million hectares (3 750 million acres) or 56 percent are located in temperate and boreal zones, predominantly in those of the industrial countries (Steinlin, 1982).

Today, the forest areas of the industrial nations are for the most part stable and may even be expanding. The long process of economic development and the production of energy from coal, petroleum and water-power have to some extent relieved the demands that used to be made on the forests. The demand for fuelwood has dropped to a minimum, and it is only since oil prices began to soar that it has once again been showing a rising tendency. In the industrialized countries farming has been intensified and no longer encroaches on the forests with pastures and scattered utilization. Production in coniferous forests is predominantly to provide sawlogs and pulpwood, while forests in steep terrain are intended to offer protection and to serve as recreational areas. The need for forest conservation is incorporated in existing laws and firmly established in public opinion. However, in spite of this favourable development, the woods of the industrial nations are imperilled by air pollution and acid rain.

The situation is altogether different in tropical forests. The rapid growth of population and extensive farming practices with shifting cultivation are the main causes of forest shrinkage. The tropical forests supply roughly 1 300 m<sup>3</sup> of timber annually; that is, about 50 percent of the timber used throughout the world. However, about 80 percent of this total is used as firewood. Only about 4 percent is exported as high-quality commercial timber.

## TIMBER UTILIZATION - A NEGATIVE CONCEPT?

Faced with the severe shrinkage of the forest areas and the threatening ecological crisis caused by population and industrial growth alike, the situation of the timber industry, too, has become more difficult. In many cases, public opinion seems to regard forest utilization as incompatible with environmental aims and objectives. However, experience gained in the temperate zones shows that primeval forests can be converted into stable commercial woodlots. Notwithstanding many problems and mistakes, it has been proved possible to bring about a balance between the demands of ecology and the needs of economic management.

In tropical forests, attempts to combine forest management with forest conservation are of relatively recent origin. However, what is of decisive importance here as regards success or failure is not so much the silvicultural methods employed but rather the improvement of farming practices in general. Only when farming conditions have been improved will it be possible to prevent the extensive burning down of wooded areas in order to cultivate the soil. Surely, this is one of the thorniest problems that must be dealt with by developing countries if they are to conserve their natural resources.



## LOGGING SYSTEMS

Varying silvicultural and economic conditions also demand different logging systems. There are no hard and fast rules in favour of either clearcutting or selective felling.

Clearcutting involves the lowest direct costs in timber harvesting and is therefore quite frequently used in the forests of the temperate zones. Given good soil and a terrain without excessively steep slopes, and provided, moreover, that reforestation is carried out speedily, the utilization of smaller woodlots measuring about 0.5 - 2 ha (1.25 - 5 acres) is ecologically unobjectionable. However, clearcutting is against the law in a number of countries, as there is no assurance of proper reforestation.

Selective logging does not, as a rule, provide any guarantee of optimum forest management. Logging is more expensive and may damage the residual stand or, indeed, make it useless altogether. In suitable forests, however, selective logging - if carried out expertly - may result in optimum protection of the soil. In fact, in protection forests on steep slopes it is the only permissible logging method.

Even today, highly mechanized harvesting systems are still transferred from industrial nations to countries with underemployment and low wage levels. But imported machines, spare parts and fuel are expensive, and the operation and maintenance of such machines by unskilled personnel under extreme conditions is difficult. In many cases, in fact, the direct transfer of such working methods is not only uneconomic but also antisocial. In countries suffering from underemployment, forest management too should aim at providing a large number of jobs. Manual labour should be replaced by machines only when this is essential for technical or economic reasons.

## FOREST DEVELOPMENT

The development of a forest region should be planned integrally over the largest possible area. Integrally should here be understood to mean that the network of forest roads and the particular logging method employed must form a single integrated system fully adapted to the locally prevailing economic and ecological conditions. Such planning must not merely concentrate on the logging operations proper, but also take into account all factors in the overall forest management plan. In this connexion, it is of particular importance to include both production and protection forests.

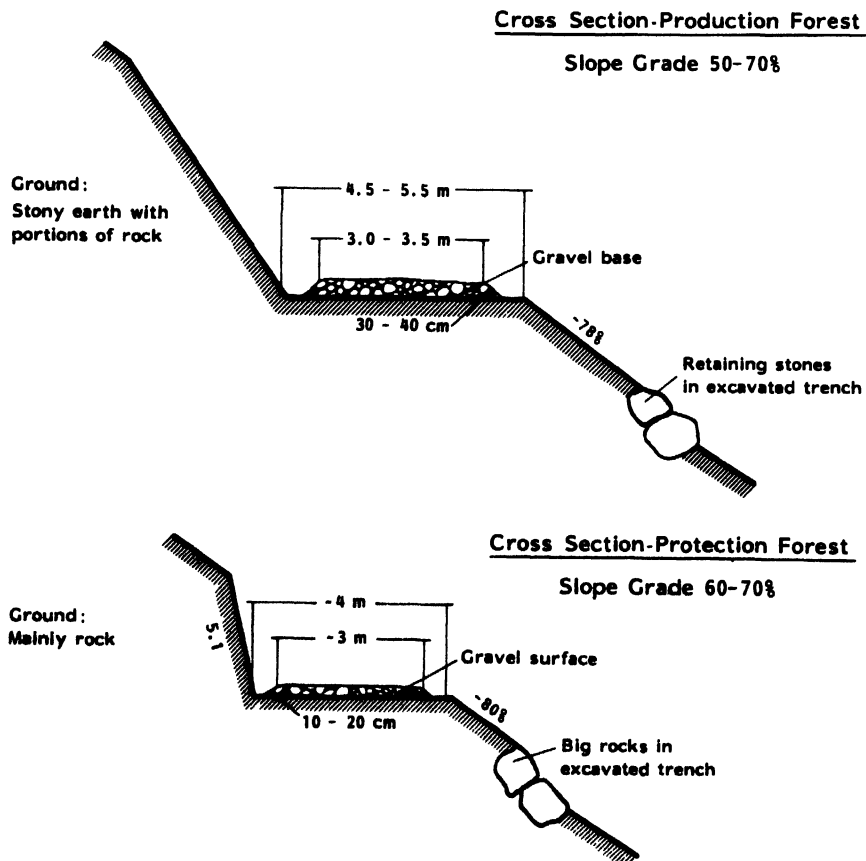
On steep sloping terrain, great importance is attached to the protective function of the forest. Here the network of forest roads is restricted to the absolute minimum. In steep terrain, mobile skyline-yarders are an efficient means of extracting logs with due consideration to forest and soil conditions.

In mountainous areas, helicopter logging would be the ideal method for protection of both the soil and the timber stand. However, in Central Europe the costs are at least US\$ 35 per m<sup>3</sup> with a maximum horizontal handling distance of about 1 000 m and a maximum difference in elevation of 300 m. These costs are so high as to make this method impracticable except in extremely difficult terrain and for the most valuable timber.

## CONSTRUCTION OF FOREST ROADS

An adequate network of forest roads is the basis of sound forest management. Its quality is to a large extent determined by that of the overall planning. In mountainous terrain in particular, the planning and construction of roads is a rather complex matter. It is most necessary to take into account the prevailing hydro-geological conditions, the hill stability, and the danger of erosion. Faulty layout of winding roads with hairpin bends has a detrimental effect on the environment. If the construction of a winding road cannot be avoided, sharp bends should - as a rule of thumb - be spaced at a minimum horizontal distance of about 1 km.

In steep terrain, the route layout essentially follows the contours in free curves. The formation width is restricted to approximately 4 - 5 m in order to cut down spoil and erosion. In the past, bulldozers used to cause severe damage as a result of primitive sidecasting. Today in difficult terrain heavy-duty hydraulic excavators are used. These machines control the movement of material more effectively and are able to pile up the rocks to form retaining walls. Modern rock-drilling machines and careful shot-blasting techniques have substantially reduced damage to the environment in rocky terrain.



Following the implementation of some road construction projects in mountainous terrain, erosion can be seen to increase markedly. An adequate drainage system must be provided during construction of the road. The slopes should be sown with grass seed as soon as possible. This operation is today carried out in major road construction projects with seeders.

In Austria, the Forestry Act contains stringent regulations on the planning and construction of forest roads. There are also pertinent nature conservation laws which likewise lay down restrictions of various kinds. This ensures that ecological demands, too, are taken into account when forest roads are constructed.

#### LOGGING SYSTEMS

The logging system should be carefully planned in advance for each individual logging area with felling, bucking, skidding, stacking and hauling adapted to one another. The greater the degree of mechanization and the capacity of a system, the greater the importance of exact planning and organization.

Narrow stretches of forest along small streams, creeks, rivers and lakes should as far as possible be left in their original state. These green strips serve to protect ecologically sensitive zones and are important elements of any natural landscape. No logging across creeks and rivers should be permitted so that damage to the embankment, as well as pollution of the water, is avoided.

In the industrial countries it is customary today even in steeply sloping wooded terrain to use processors to carry out the primary conversion of felled trees right on the forest road - a compelling economic necessity in view of the current high wage costs. However, full-tree skidding takes from the forest soil a substantial part of its nutrients because the branches, leaves, twigs, etc. are removed. This means that on the stony, poor soil of mountain forests, a highly mechanized logging system may have detrimental consequences. The use of large heavy-duty machines in terrain of this kind should be restricted for ecological reasons.

#### SKIDDING

Ground skidding inflicts damage on both the forest soil and the timber stand, so this part of the timber harvest, too, requires careful planning and implementation. The extraction machines should travel only along the skid trails intended for this purpose, the logs being pulled up with the aid of winches.

Under the conditions prevailing in Central Europe, wheeled skidders are the most economic means of extracting timber on sloping terrain with a gradient of up to 30 percent. To reduce the ground pressure and consequently the damage inflicted on the soil, these skidders are increasingly being equipped with wider tyres.

Owing to the severe soil erosion and destruction of the forest involved, there is a strong argument against construction of skid trails and roads on steep sloping terrain. Here ecological aspects clearly take precedence over economic considerations. Regardless of the higher cost involved, cable yarding is the correct method in this case.

In alpine forests, manual ground skidding by gravity is still being used - a centuries-old traditional method which does not require any external supply of energy. While this method is both simple and cheap over distances of up to about 300 m, especially in farm woodland and for smaller forestry enterprises, it is contingent on the availability of experienced skilled labour and special tools. If used wrongly, manual ground skidding may also lead to severe erosion damage.

## YARDING

On the difficult terrain encountered in the alpine regions of Central Europe, the use of mobile yarders has today become indispensable in wood harvesting. Depending on type of machine and cable lengths, they may cover distances from 300 m to 700 m and require a network of forest roads comprising about 15 - 25 m/ha (6 - 10 m/acre). Also the traditional skyline yarding systems with partially or fully suspended load will inflict only a minimum of damage on the soil and on the timber stand. In industrialized countries with high labour costs, however, extraction costs are about 50 to 100 percent higher than with modern skidders.

With an integrated, combined system of forest roads and modern yarding methods, mountain forests can be managed in an economically and ecologically correct way. The careful application of forestry engineering concepts assists us in utilizing the world's forests and conserving them at the same time.

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Dynapac roller often used for subgrade compaction in properly designed forest roads

(Photo: R. Heinrich)

## INTRODUCTION TO A CHECKLIST FOR ERGONOMIC EVALUATION OF FOREST MACHINES

by

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### 1. INTRODUCTION

Ergonomic checklists help to evaluate working systems and to organize work. In recent years, checklists have been compiled by various countries for different applications. Some of them are very general, some serve a specific purpose.

The checklists are questionnaires based on ergonomic principles and yield analyses which describe working situations fully and systematically. Their informative value depends on the scope and precision of the questions and on the skill of the user. A quick evaluation is a major function of these checklists.

A "Checklist for the Ergonomic Evaluation of Forest Machines" by Dr. Rehschuh and Dr. D. Tzschöckel, Mitteilung des KWF - volume XIX, 1977 was developed for the work-economics department of the Board of Forestry Works and Techniques. The present list is based on experience gained in applying the first and second drafts and other domestic and foreign checklists and on discussions with various authorities. Application of the checklist requires knowledge of ergonomics; it is recommended for use by authorities controlling forest road works, by heads of machine yards and forest-techniques centres, by designers of forest machines and by instructors at educational institutions.

The checklist, as the title indicates, is designed for the evaluation of forest machines - with the exception of portable power devices - and consists of a questionnaire and explanations. The explanations are intended to make answering easier and to enable general standards to be applied to the answers. International standards are included as far as they are known and applicable.

Since not all evaluation items are standardized, the explanations contain reference values which are taken from technical publications. These values are related to standards and regulations applied in the Federal Republic of Germany and must be adjusted for use in other countries. The values given correspond to the present state of work study findings and should be continually updated and adjusted.

The checklist is divided into three parts:

Part A is a general description and includes description of the machine and technical data.

Part B is the main part and contains individual questions for the ergonomic evaluation. The appropriate square is checked off (+, 0, -). If the question does not apply, this should be indicated by an entry of N/A (not applicable).

Plus answers to the questions in part B lead to the assumption that the solution is ergonomically favourable; a zero means that it is partly favourable; minus answers indicate an ergonomically unfavourable judgement.

Part C contains a summary and recommendations. If the ergonomic utility of a machine is to be judged (for example for comparison with other machines), it may be enough to answer the questions in part C, which should therefore be carefully completed.

CHECKLIST  
FOR ERGONOMIC VALUATION  
OF FOREST MACHINES

by  
D. Rehschuh and  
D. Tzschöckel

Report of KWF Volume XIX  
published by  
Federal Centre of Forest Operations and Techniques (KWF)  
1979

## PREFACE

1. This ergonomic checklist was compiled by the Federal Centre for Forest Operations and Techniques (KWF), Federal Republic of Germany. Experience and publications available inside and outside the country were considered. A first and a second version of the checklist were tried out extensively and were discussed with various institutions before this final version was drawn up.
2. The application of this checklist requires a knowledge of ergonomics. It is especially intended for use by institutions engaged in testing forest machines, for heads of machine centres and for constructors of forest machines. It can also be used as a teaching aid.
3. The checklist has been developed for all forest machines except portable powered machines such as one-man chainsaws.
4. The checklist consists of one section containing questions and another with general comments. This additional section is available only in German. It can be supplied by KWF upon special request.
5. The general comments are intended to facilitate answering the individual questions. They include available national standards and some international standards. Where such standards were lacking, an attempt has been made to provide relevant technical data extracted from literature. These data (e.g. average body measurements) are primarily related to the Federal Republic of Germany and should be amended if used elsewhere. The data given correspond to the present state of scientific knowledge. It is therefore necessary to update and amend them continually.
6. Section A covers a general description of the tested machine.
7. Section B is for ergonomic testing of the machine. Checking is either with a plus sign (+) (=ergonomically favourable), a zero sign (0) (=ergonomically partly favourable) or a minus sign (-) (=ergonomically unfavourable). If a question is not applicable, it is marked N/A.
8. Under each question there is space for additional remarks, e.g. on desirable improvements to the machine and on data measured. At the end of each chapter there is space for comments on other important facts such as origin of data from other sources (manufacturer, publications).
9. Section C contains a summary and recommendations. If the aim is to compare different machines it may be sufficient to answer only the questions in this section. It should therefore be done comprehensively.
10. KWF would welcome comments on practical results obtained by using this checklist and on suggestions for improvements.

A. CHECKING AND MACHINE DESCRIPTION:

1. Checking Checking No.:

1.1 Purpose of checking: \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

1.2 Measuring devices applied: \_\_\_\_\_  
\_\_\_\_\_

1.3 Operation carried out during checking: \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

1.4 Conditions at the time of checking: \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

1.5 Machine licensed for public traffic on: \_\_\_\_\_  
by: \_\_\_\_\_

1.6 Technical reports on machine available: \_\_\_\_\_  
issued by: \_\_\_\_\_

1.7 Checking:

---

(Place)

(Date)

(Checking-Sections)

(Observer)



2. General description of machine

2.1 Machine or aggregate unit:

\_\_\_\_\_  
(Producer's name and address)

\_\_\_\_\_  
(Model and designation)

\_\_\_\_\_  
(Serial no.)

\_\_\_\_\_  
(Year of construction)

2.2 Additional equipment (type, model and designation, producer):

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

2.3 Subsequently mounted or built-in component parts or devices: \_\_\_\_\_

\_\_\_\_\_

2.4 Mode of travel: \_\_\_\_\_

\_\_\_\_\_

2.5 Employment of machine for: \_\_\_\_\_

\_\_\_\_\_

2.6 Performance limits of machine: \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

2.7 Hours of operation of machine up to present: \_\_\_\_\_

\_\_\_\_\_

2.8 Hours of operation required per annum: \_\_\_\_\_

\_\_\_\_\_

2.9 Other important facts: \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

3. Technical data

3.1 Vehicle (machine)

3.1.1 Design: \_\_\_\_\_

3.1.2 Permissible total weight (kg): \_\_\_\_\_

3.1.3 Permissible axle load (kg) front: \_\_\_\_\_ rear: \_\_\_\_\_

3.1.4 Dimensions (mm): \_\_\_\_\_

3.1.5 Turning radius (m): \_\_\_\_\_

3.2 Engine (drive)

3.2.1 Design: \_\_\_\_\_

3.2.2 Rated speed ( $\text{min}^{-1}$ ): \_\_\_\_\_

3.2.3 Power take-off speed ( $\text{min}^{-1}$ ): \_\_\_\_\_

3.2.4 Performance kW: \_\_\_\_\_

3.3 Gear unit

3.3.1 Design: \_\_\_\_\_

3.3.2 Number of forward gears: \_\_\_\_\_ reverse gears: \_\_\_\_\_

3.3.3 Drive: \_\_\_\_\_

3.4 Steering: \_\_\_\_\_

3.5 Brakes: \_\_\_\_\_

3.6 Tire dimensions front: \_\_\_\_\_ rear: \_\_\_\_\_

3.7 Further technical data: \_\_\_\_\_

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

3.8 Other important facts: \_\_\_\_\_

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

B. ERGONOMIC EVALUATION

		+	0	-	<u>1/</u>
1.	<u>Mounting and alighting</u>				
1.1	Are the steps easy to reach and sufficiently long and wide? _____	_	_	_	
1.2	Is the surface of steps made of non-skid material? _____	_	_	_	
1.3	Are the steps designed to resist damage by terrain obstacles? _____	_	_	_	
1.4	Are there enough handles for mounting and alighting and are they conveniently placed? _____	_	_	_	
1.5	Is the space for mounting and alighting sufficiently wide and high to avoid undue discomfort? _____	_	_	_	
1.6	Is the space provided for mounting and alighting free of sharp edges and projecting obstacles? _____	_	_	_	
1.7	Can the operator's seat or stand be reached without undue discomfort caused by levers or the like? _____	_	_	_	
1.8	Is it possible to leave the machine quickly in case of emergency? _____	_	_	_	
1.9	Other important facts: _____ _____ _____				

1/ + = yes, 0 = to some extent, - = no, N/A = not applicable

The same evaluation scheme is to be applied on the following pages

2. Operator's cab

2.1 Are interior dimensions of the operator's cab sufficient for comfortable machine operation? ☐ ☐ ☐

---

2.2 Is the operator safe from sharp edges, points or projections? ☐ ☐ ☐

---

2.3 Is the whole cab suspended separately from the body? ☐ ☐ ☐

---

2.4 Are all windows made of safety glass? ☐ ☐ ☐

---

2.5 Is the cabin floor made of non-skid material? ☐ ☐ ☐

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2.6 Is the operator's cab as a whole sturdy and safe? ☐ ☐ ☐

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2.7 Other important facts:

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3. Operator's seat

3.1 Is the seat conveniently placed? ☐ ☐ ☐

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3.2 Can the seat be turned if necessary? ☐ ☐ ☐

---

3.3 Is there a backrest and is it appropriate? ☐ ☐ ☐

---

3.4 Is the seat sprung, is it shock-absorbing, and is the springing adjustable? ☐ ☐ ☐

---

3.5 Are the dimensions of the seat (depth, width, height) and inclination appropriate? ☐ ☐ ☐

---

3.6 Are positions of seat and backrest adjustable and can they be locked? ☐ ☐ ☐

---

3.7 Are seat and backrest appropriately shaped? ☐ ☐ ☐

---

3.8 Is padding of seat and backrest appropriate as to amount and material? ☐ ☐ ☐

---

3.9 If required, are there conveniently located arm- and foot-rests? ☐ ☐ ☐

---

3.10 Other important facts:

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---

4. Instruments

4.1 Are there all instruments necessary for operation? ☐ ☐ ☐

---

4.2 Are the types of instruments appropriately chosen? ☐ ☐ ☐

---

4.3 Are the instruments satisfactorily located? ☐ ☐ ☐

---

4.4 Do the instruments give clear, unambiguous and relevant information? ☐ ☐ ☐

---

4.5 Are the most important and most frequently used instruments placed in the central field of view? ☐ ☐ ☐

---

4.6 Are all instruments well-spaced for reading and are letters, figures and indicators big enough to permit quick and correct reading? ☐ ☐ ☐

---

4.7 Are marks and graduations of scales appropriately chosen? ☐ ☐ ☐

---

4.8 Are zero-positions and directions of indicator movement conveniently chosen? ☐ ☐ ☐

---

4.9 Are there adequate warning signals, are they obvious and easy to distinguish? ☐ ☐ ☐

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4.10 Other important facts:

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5. Controls

- 5.1 Are the controls appropriately arranged? ☐ ☐ ☐
- 
- 5.2 Are the types of controls appropriately chosen? ☐ ☐ ☐
- 
- 5.3 Are the controls easy to see and to distinguish? ☐ ☐ ☐
- 
- 5.4 Is safe operation guaranteed by size and shape of controls, are controls handy and made of non-skid material (foot pedals)? ☐ ☐ ☐
- 
- 5.5 Are the directions of movement logical? ☐ ☐ ☐
- 
- 5.6 Are surface and surrounding parts of controls free of sharp and pointed edges? ☐ ☐ ☐
- 
- 5.7 If required, can various controls be operated simultaneously without difficulty? ☐ ☐ ☐
- 
- 5.8 If useful, are there various controls for the same operation attached to different parts of the machine? ☐ ☐ ☐
- 
- 5.9 If gloves and special shoes are worn, can controls be properly operated? ☐ ☐ ☐
- 
- 5.10 Can all controls be reached and operated without hindrance? ☐ ☐ ☐
- 
- 5.11 Can controls be operated with minimum physical effort? ☐ ☐ ☐
- 
- 5.12 Other important facts:

6. Visibility

6.1 Can the operator always see the road and the working object without having to assume a twisted or awkward body position? ☐ ☐ ☐

---

6.2 Can the operator see the whole working distance of mobile machine parts and devices from beginning to end? ☐ ☐ ☐

---

6.3 Are there any plugs for working lights or hand lamps on the machine? ☐ ☐ ☐

---

6.4 If working lights are required and available, are they sufficient in number, adjustability and intensity? ☐ ☐ ☐

---

6.5 Are all lights protected by wire guards? ☐ ☐ ☐

---

6.6 Is there interior lighting in the operator's cab? ☐ ☐ ☐

---

6.7 Are there appropriate windscreen wipers? ☐ ☐ ☐

---

6.8 Are there any devices for drying or defrosting windscreens, if required? ☐ ☐ ☐

---

6.9 Other important facts:

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7. Influences detrimental to health

7.1 Is the operator's seat or stand sheltered against the weather? ☐ ☐ ☐

---

7.2 Can heating and air-conditioning in the operator's cab be appropriately adjusted? ☐ ☐ ☐

---

7.3 Is the operator's seat or stand sufficiently protected against dirt and humidity? ☐ ☐ ☐

---

7.4 Are the operating personnel protected against inconvenient or dangerous exhaust gases or fumes? ☐ ☐ ☐

---

7.5 Is the noise level to which the operating personnel are exposed below the health-risk limit? ☐ ☐ ☐

---

7.6 Is the noise level to which persons working in the immediate surroundings of the machine are exposed below the health-risk limit? ☐ ☐ ☐

---

7.7 Are the operating personnel protected against impairment of or damage to health by vibration? ☐ ☐ ☐

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7.8 Other important facts:

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8. Physical and mental work load

8.1 Are frequent peak loads of work avoided? ☐ ☐ ☐

---

8.2 Is a predominantly static muscular strain avoided? ☐ ☐ ☐

---

8.3 Can the machine be operated without having to assume a twisted, bent or unfavourable body position? ☐ ☐ ☐

---

8.4 Is the physical workload likely to be under the tolerable continuous performance limit? ☐ ☐ ☐

---

8.5 Is excessive strain on eyes and ears avoided? ☐ ☐ ☐

---

8.6 Is excessive strain on concentration, attention, and work precision avoided? ☐ ☐ ☐

---

8.7 Is the chance that operational errors have serious consequences kept to a minimum? ☐ ☐ ☐

---

8.8 Is there another kind of work which can be done alternately with machine operation? ☐ ☐ ☐

---

8.9 Other important facts:

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9. Safety

9.1 Are the operating personnel sufficiently protected against falling and piercing objects? ☐ ☐ ☐

---

9.2 Are there sufficient and appropriate protection and safety devices? ☐ ☐ ☐

---

9.3 Is the machine equipped with a radio communication set and distress signal for cases of emergency? ☐ ☐ ☐

---

9.4 Are the operating personnel protected against oil spraying out of a damaged hydraulic unit? ☐ ☐ ☐

---

9.5 Is sealing and protection against leakage sufficient if substances damaging to health are handled or processed? ☐ ☐ ☐

---

9.6 Can auxiliary devices be joined or mounted easily and safely? ☐ ☐ ☐

---

9.7 Is there any first-aid material? ☐ ☐ ☐

---

9.8 Are there safety belts available if required? ☐ ☐ ☐

---

9.9 Is there an appropriate and easily accessible fire extinguisher? ☐ ☐ ☐

---

9.10 Are the tire valves protected against damage? ☐ ☐ ☐

---

9.11 Are tank and tank cap placed safely? ☐ ☐ ☐

---

9.12 Is the machine sufficiently protected against use by unauthorized persons? ☐ ☐ ☐

---


9.13 Other important facts:

10. Instructions for use

10.1 Are there sufficient instructions for use, safety and maintenance found on the machine?

□ □ □

10.2 Are the instructions appropriately located, durably attached, easily seen, clear and understandable?



10.3 Is there an instruction booklet, is it permanently available and are all items relevant and easy to understand?

□ □ □

10.4 Other important facts:

This image shows a single sheet of white paper with horizontal ruling lines. The lines are evenly spaced and run across the width of the page. There are no margins, text, or other markings on the paper.

11. Maintenance and repair

11.1 Are the individual parts which must be reached for maintenance and repair easy to see and reach? ☐ ☐ ☐

---

11.2 Can a safe foothold be kept when maintaining or repairing the machine? ☐ ☐ ☐

---

11.3 Are there sufficient steps, stepladders and handles to ensure a safe foothold during repair jobs? ☐ ☐ ☐

---

11.4 Are the steps and platforms used during repair work equipped with non-skid surface? ☐ ☐ ☐

---

11.5 Can maintenance and repair works be carried out without danger of injury from pointed, sharp or projecting elements? ☐ ☐ ☐

---

11.6 Can maintenance and repair works be carried out without lifting or moving heavy objects? (covers, etc.) ☐ ☐ ☐

---

11.7 Can maintenance and repair works be carried out without getting dirty from lubricants (oil and grease)? ☐ ☐ ☐

---

11.8 Is the service tool kit sufficiently equipped and are spare parts available? ☐ ☐ ☐

---

11.9 Are the boxes containing service tools and spare parts conveniently located and can these boxes be locked? ☐ ☐ ☐

---

11.10 Do the instructions for use contain sufficient guidelines for maintenance and repair? ☐ ☐ ☐

---

11.11 Is there a spare-part list available? ☐ ☐ ☐

---

11.12 Other important facts:

C. CONCLUSIONS AND RECOMMENDATIONS

1. Summary of ergonomic evaluations

1.1 Mounting and alighting

Measurement results, advantages, disadvantages, importance:

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---

Suggestions for change

indispensable: 

---

---

desirable: 

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Additional statements: 

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Judgement: 

---

1.2 Operator's cab

Measurement results, advantages, disadvantages, importance:

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Suggestions for change

indispensable: 

---

---

desirable: 

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Additional statements: 

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Judgement: 

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1.3 Operator's seat

Measurement results, advantages, disadvantages, importance:

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Suggestions for change

indispensable: \_\_\_\_\_

---

desirable: \_\_\_\_\_

Additional statements: \_\_\_\_\_

---

Judgement: \_\_\_\_\_

1.4 Instruments

Measurement results, advantages, disadvantages, importance:

---

---

Suggestions for change

indispensable: \_\_\_\_\_

---

desirable: \_\_\_\_\_

---

Additional statements: \_\_\_\_\_

---

Judgement: \_\_\_\_\_

1.5 Controls

Measurement results, advantages, disadvantages, importance:

---

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Suggestions for change

indispensable: \_\_\_\_\_

---

desirable: \_\_\_\_\_

Additional statements: \_\_\_\_\_

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Judgement: \_\_\_\_\_

1.6 Visibility

Measurement results, advantages, disadvantages, importance:

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Suggestions for change

indispensable: \_\_\_\_\_

desirable: \_\_\_\_\_

Additional statements: \_\_\_\_\_

Judgement: \_\_\_\_\_

1.7 Influences detrimental to health

Impact and significance: \_\_\_\_\_

Suggestions for change

indispensable: \_\_\_\_\_

desirable: \_\_\_\_\_

Additional statements: \_\_\_\_\_

Judgement: \_\_\_\_\_

1.8 Physical and mental load

Impact and significance: \_\_\_\_\_

Suggestions for change

indispensable: \_\_\_\_\_

desirable: \_\_\_\_\_

Additional statements: \_\_\_\_\_

Judgement: \_\_\_\_\_



1.9 Safety

Impact and significance: \_\_\_\_\_

\_\_\_\_\_

Suggestions for change

indispensable: \_\_\_\_\_

desirable: \_\_\_\_\_

Additional statements: \_\_\_\_\_

Judgement: \_\_\_\_\_

1.10 Instructions for use

Impact and significance: \_\_\_\_\_

\_\_\_\_\_

Suggestions for change

indispensable: \_\_\_\_\_

desirable: \_\_\_\_\_

Additional statements: \_\_\_\_\_

Judgement: \_\_\_\_\_

1.11 Maintenance and repair

Impact and significance: \_\_\_\_\_

\_\_\_\_\_

Suggestions for change

indispensable: \_\_\_\_\_

desirable: \_\_\_\_\_

Additional statements: \_\_\_\_\_

Judgement: \_\_\_\_\_

2. Special reference to machine operation

2.1 Qualifications expected from and requirements imposed on operating personnel

2.1.1 What requirements are imposed on the operating personnel?

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2.1.2 Is there special knowledge necessary or desirable for machine operation?

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2.1.3 Is there special training or practice necessary for machine operation?

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2.2 Organization of work and rest periods

2.2.1 Is more than one person required for machine operation?

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2.2.2 Can and must rest periods be taken? \_\_\_\_\_

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Is a regular change of the operating personnel necessary? \_\_\_\_\_

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2.2.3 What are the requirements imposed on the work organizers? \_\_\_\_\_

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3. Concluding ergonomic judgement

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BASIC INFORMATION ON WORK ORGANIZATION, DATA COLLECTION,  
ERGONOMICS AND SAFETY AT WORK

by

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1. OBJECTIVE OF WORK STUDIES AND ERGONOMIC INVESTIGATIONS

The objective of work studies and ergonomic investigations is to develop optimum techniques and systems for the worker and for each individual enterprise. For this purpose, not only the interaction of man and machine, but also the requirements of the enterprise must be carefully analysed. In most cases, the enterprise aims at reducing costs and/or increasing profitability, whereas the worker is primarily interested in maintaining his capacity to work, obtaining an adequate compensation for his efforts, and making the best use of tools and equipment.

In order to achieve these goals, those engaged in work studies use a number of different procedures. The study of work is based on:

methods engineering	- interaction of man and machine
data collection	- time, reference bases and determinants
ergonomics	- humanizing work, optimum adaptation of work to man
work safety	- accident prevention, use of safety equipment

2. METHODS ENGINEERING

The organization of work is one of the main objectives of work studies. Only if work is organized systematically will it yield optimum results.

According to Frauenholz, work organization takes place at three levels:

- planning: management of the enterprise (i.e. by the head forester)
- organization: administration of the district (i.e. by the forester)
- execution: performance of the work by the individual worker

Frauenholz argues that for adequate decision-making and successful operations, information must flow both vertically among all three levels and horizontally in all directions, as only in this way will the required feedback be assured.

Work organization is determined by the structure of the enterprise, the tools and machinery to be used and, of course, the personnel employed by the enterprise. In general, experience gained with working techniques and relevant principles form the basis of methods engineering. From this it follows that methods engineering can never be restricted to a single measure, but always requires a continuous effort, in which all those involved are constantly learning and gaining new experience.

Basically, two procedures may be followed in organizing work:

a) The engineering method

This method will be successful only if the work organizer has in-depth expert knowledge, if he uses models and has a high degree of creativity;

b) The investigative method

In this method, work is systematically analysed. All factors that influence operations must be studied together with the human aspects of the job, such as time, wages and costs. The results of such studies permit an optimum organization of work. This procedure is most extensively used when rapid progress is desired.

REFA 1/ recommends a six-phase approach to the above-mentioned two methods:

- Phase one: setting organizational, human and economic objectives
- Phase two: defining tasks for each work place, each team, and the enterprise as a whole
- Phase three: seeking ideal solutions
- Phase four: gathering data and looking for feasible solutions
- Phase five: selecting optimum solutions (technologically safe, economically acceptable and tolerable in human terms)
- Phase six: introducing solutions and controlling their application

2.1 An example of methods engineering as put forward by Frauenholz. Work organization in thinning operations

The cost for the extraction of 1 m<sup>3</sup> of wood removed in thinning and its transport to the storage area was studied using three different procedures under similar conditions. In each case, conversion was carried out with minimum damage to the stand and with due regard to ergonomics.

Tools and machinery used: light power-saw; Steyr tractor with Steyr bogie; manual tools required for thinning; and protective equipment. The workers were thoroughly trained, familiar with the work and had adequate practice. Period of observation: one week.

Version A: Felling and conversion, as well as crosscutting, was carried out in one work cycle. After three to nine trees were felled and crosscut they were moved by hand to the skidding trail, where they were stored ready for extraction. Skidding started only after completion of felling operations. Further handling was carried out at the storage site, if necessary. Costs were low because the immediate conversion of the wood required only minor further handling. With this method, skidding involves no major difficulties and causes hardly any damage to the stand.

Ergonomically favourable method.

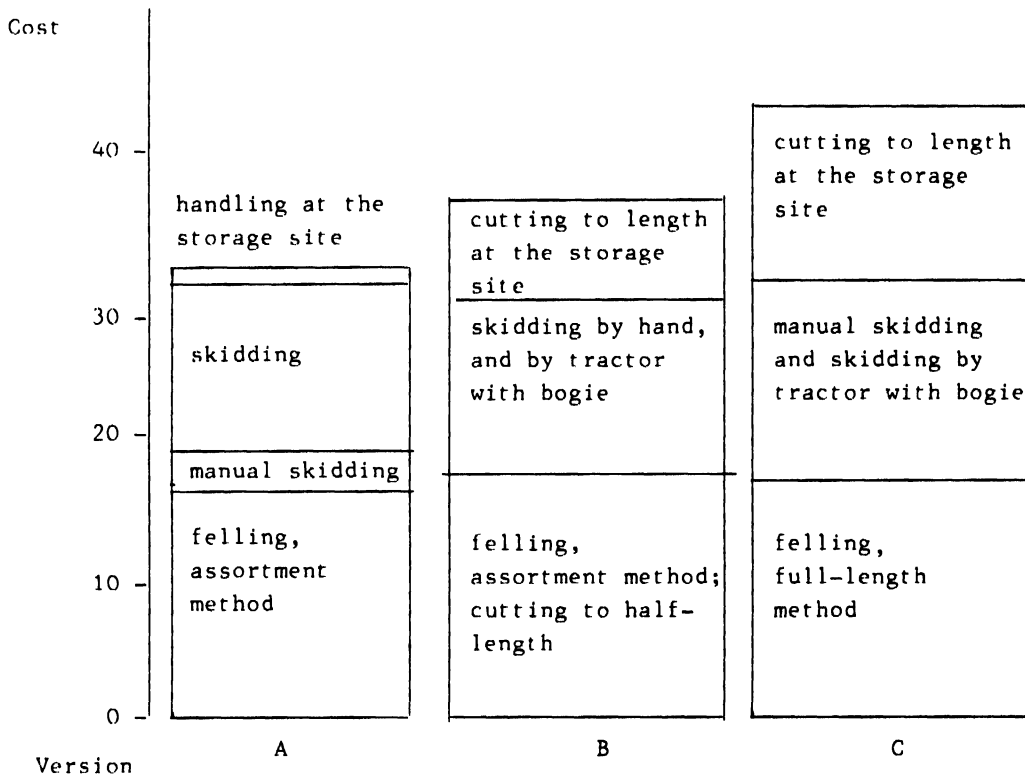
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1/ A time study advisory group in Germany

Version B: Felling and conversion as with Version A, but cutting trees to half-length in the stand. Skidding in half-length. Further crosscutting at the storage site resulted in higher costs.

No apparent cost reduction in skidding was achieved.

Version C: Felling and delimbing in the stand. Conversion at the storage site. The separation of the felling operation and conversion at the storage site, as well as the rather difficult extraction of the full-length trees from the stand, resulted in high costs.



This study showed clearly that work planning (choice of the assortment or full-length method) has a considerable influence on costs. The results apply, however, only to work carried out with the above-described tools and equipment under identical working conditions.

## 2.2 Work procedure

Each operation consists of a sequence of work cycles, for example:

### Felling

cutting  
delimbing  
crosscutting

### Skidding

empty travel  
attaching load  
loaded travel  
detaching load

In accordance with the principle that it is better to subdivide each operation into too many than too few elements, these cycles can be subdivided into individual phases. It is important to define accurately the measuring points (beginning and end of each cycle) and to observe these in analysing and timing the work.

### 2.3 Example of subdivision into phases

Cutting - operator time - genuine working time (GWT). (See 3.4.1)

<u>Phase</u>	<u>Measuring point</u>
felling the tree	
walking to the tree	depositing of tools
cleaning of the root collar	
cutting the notch	putting the one-man saw down
felling cut	putting the one-man power-saw down
wedging	depositing the axe
delimbing (including walking)	end of delimbing
crosscutting, measuring	reading and rolling up the measuring tape
	end of cut

The cycle time ends with the completion of the work on the tree.

Skidding with bogie - operator time - GWT.

<u>Phase</u>	<u>Measuring point</u>
empty travel (if necessary subdivision into sections)	where the rear wheels of the vehicle pass the defined section. If no subdivision into sections is made, when the wheels come to a standstill
pulling out cable	laying down cable
attaching the load	when choker cable or chain is put around the stems or when these are attached to hook of traction cable
pulling load toward vehicle	load touches the skidder blade
loaded travel	see empty travel
second load	begins when load is lowered and ends when it touches the skidder blade again
detaching load	cable pulled in, skidder starts moving for empty travel or for storage operations
storing logs	skidders starts moving for unloaded travel

Cycle time ends with the beginning of the next unloaded travel.

### 3. DATA COLLECTION

The method and scope of a work study are determined, to a great extent, by the way in which the data are to be applied. A general time study may suffice to get an idea of the machinery and equipment to be used, whereas detailed data are required for working out piece-rate systems. Thus a decision must be taken in each case on the purpose and extent to which work studies are to be made. Time studies permit work procedures and costs to be assessed and are the basis on which methods engineering can be carried out.

#### 3.1 Types of data

Time categories  
Reference values  
Parameters

#### 3.2 Breakdown of time

Operator time  
Machine time  
Materials time

Operator time differs from the other categories in a number of ways, but primarily in that it includes a rest allowance. Machine time covers the period during which tools or equipment are used. Materials time indicates primarily the duration of timber processing in the forest enterprise.

#### 3.3 Time studies

Three time-taking methods are used:

- cumulative timing
- cycle timing
- activity sampling

##### 3.3.1 Cumulative timing

For this method, a stop-watch graduated with 60 or 100 divisions is required.

The times taken at each measuring point are continuously recorded and the work performed in each cycle is described. Thus the complete working procedure is continuously recorded. For evaluation, the time taken for each cycle is calculated by subtracting the other time values.

##### 3.3.2 Cycle timing

A special type of stop-watch is used. When the watch is stopped, one hand is arrested, whereas a second hand begins to run from zero. The time taken may be either continuously recorded as with the cumulative timing method, or entered in a coded column. In evaluating the recorded figures, it is not necessary to perform the calculations required by the cumulative timing method.

### 3.3.3 Activity sampling

With this method, time is not recorded. The work procedure is observed, and at given intervals (i.e. 50/100 or one minute) the work elements which occurred in the work phase are indicated by dots or dashes in the corresponding column, or symbols designating certain phases are used to indicate the frequency of work elements. Here, strict adherence to the given observation interval is of particular importance.

## 3.4 Time categories

### 3.4.1 Genuine working time (GWT)

This includes all types of time required for performing the job and resulting exclusively from the tasks assigned. These time categories contribute directly to the progress of work.

### 3.4.2 General time (GT)

This does not contribute directly to the progress of work, but is essential for performing the assigned job. General time comprises changeover time and allowances, including rest allowance.

Changeover time: Preparation of work and restoring tools and equipment to their original state after work has been completed (e.g. covering power-saw blade and removing cover)

Job-related  
allowance: e.g. filling, sharpening and repairing power-saw

Personal  
allowance: e.g. handling work clothes, attending to personal needs, etc.

Organization-  
related allowance: e.g. discussions with head forester or with other colleagues

Rest allowance: all breaks serving the recuperation of the individual (excluding, however, coffee and lunch breaks).

### 3.4.3 Total working time (TWT)

This consists of GWT and GT. In assessing TWT, GWT is assumed to be 100% and GT is computed as a percentage of it. The reason for this procedure is that GT occurs irregularly and can thus be expressed as an allowance which is added to GWT per unit (i.e. minutes per m<sup>3</sup>, minutes per trip).

## 3.5 Reference values

Such values as, for example, the mean diameter of length of a tree, its branchiness, the distances to be driven, tree volume, etc. must be determined.

## 3.6 Parameters

The inclination of slopes, the gradient of routes, the accessibility of the terrain, weather conditions, etc., are examples of factors which influence work output.



#### 4. ERGONOMICS

The term ergonomics is derived from the Greek words "ergon" (work) and "homos" (order). In the widest sense, the term ergonomics denotes the science of human work, which observes, analyses and determines general principles for humanizing work. Ergonomics comprises a number of disciplines, such as work physiology, work psychology, work hygiene, work safety and protection. The objective of ergonomics, i.e. the coordination of man and work, must be achieved in two ways:

- through tailoring work to man, through methods engineering, selection of suitable tools and machinery, the development of humanized working procedures and methods; and
- through adaptation of man to work through optimum education and training.

##### 4.1 Rating human work

According to Rohmert, work must be assessed on the basis of the following criteria:

- Is it feasible?
- Is it tolerable?
- Is it acceptable?
- Does it offer satisfaction?

##### 4.2 Types of human work in the perspective of ergonomics

In principle, human work may be broken down into energy-consuming and information-processing activities.

###### 4.2.1 Physical (energy-consuming) activities

Muscular or physical work may be static or dynamic. Static work (such as postural or holding work) is characterized by a drastically reduced blood flow. In dynamic work, groups of muscles and the limbs are used. Normally, the capacity of the cardiovascular system imposes a limit on this type of work.

###### 4.2.2 Mental (information processing) activities

In mental or brain work, the central nervous system and memory are used for receiving or passing on information.

##### 4.3 Vitality and performance capacity

The human organism is subject to periodic fluctuations in its physiological performance capacity. The daily biological rhythm reaches a performance peak at about 9 a.m. and subsequently drops to its lowest point at about 3 p.m. A second somewhat lower peak is reached at about 8 p.m., which is followed by a steep decline. The absolute performance minimum occurs at about 3 a.m.; from then onward, performance capacity rises until it reaches the morning peak. The capacity of the cardiovascular system can be increased through training and practice, but the daily biological rhythm always follows this pattern.

#### 4.4 Stress and strain

The effect of work on man is called stress. Irrespective of skills, capabilities and qualities, continuous exertion leads to stress.

Stress consists of quantifiable and observable factors whose effect on man can be appraised. Stress can be described as a function of the level and duration of exertion. The question arises as to how stress factors can be measured and with what accuracy stress can be defined. An additional problem involved in stress studies is that people exposed to the same stress experience it at different levels.

##### 4.4.1 Stress studies

Stress resulting from work and the working environment may be assessed according to the following criteria:

- duration of stress - time measurements
- mechanical characteristics
- energy consumption rate
- physical influences of the environment.

The fact that a fuel is required for generating energy (food for strength) means that the energy consumption rate can be measured. A portion of the energy generated is used for keeping the machine (i.e. the human body) running. This is called the basic metabolic rate. Depending on height, body weight and age, this amounts to some 8 000 kilojoules. For leisure activities and rest, another 2 000 kilojoules must be added. On a normal diet, the energy input corresponds to some 20 000 kilojoules over 24 hours so that approximately 10 000 kilojoules are available for energy consumption through work. (This figure applies to men only.) In addition to the time-consuming measuring procedure, the difficulty involved in determining the energy consumption rate stems from the fact that only a substantial amount of dynamic work will yield reliable values.

Physical environmental factors influence man in many ways. These include, for example: noise, vibration, climate, pollutants.

Particularly in technologically advanced, highly mechanized work, man is exposed to noise. Normally the sound level is expressed, measured and recorded in decibels A (dB(A)). The sound level is determined with the aid of calibrated measuring instruments, which also permit a reading of the noise levels of different frequencies (Hz). The evaluation (A) gives the noise levels which correspond most closely to man's experience of sound intensities.

According to Austrian standards, the sound level (equivalent continuous sound level) should not exceed 85 dB(A), with an average exposure time of eight hours, the usual duration of a shift. Whenever this level is exceeded, sound-protection equipment must be used. Noise protection may be active, i.e. insulation of machinery, or passive, i.e. wearing earplugs or earmuffs. Stress resulting from sound exposure is called noise annoyance, if it presents a disturbance or a health hazard. The hazard can range all the way from impaired hearing to complete deafness.

Stress resulting from vibrations is defined, like sound, in terms of frequency, intensity (path, speed, acceleration) and exposure time.

Especially in forestry, the climate is an important stress factor. Effective temperature, expressed as a general climate value, is derived from air temperature, humidity and wind velocity (according to Yaglou).

Further stress factors are gases, vapours, radiation and dust. Maximum permissible concentrations (MPC) at the worksite have been determined for a large number of pollutant emissions. (In Austria, MPC values have been set for some 400 pollutants.) These maximum levels must not be exceeded. The health hazard resulting from excessive exposure to pollutants can be reduced by use of special protective equipment and clothes, as well as by shortening exposure time.

Stress studies have permitted an in-depth analysis of quantifiable stress factors or elements which influence man in the execution of various operations, or to which he may be exposed as a result of technical, ergonomic or organizational patterns of work. Stress is seen as a function of exertion, individual character, capacity, and skills (Manual of Methods Engineering, Institute for Applied Work Science).

#### 4.5 Exertion studies

The parameters to be observed in working men and on the worksite have been determined. Many different stress factors influence and burden the cardiovascular and respiratory systems, particularly in forest work. The most frequent method used for determining exertion is pulse rate (PR) measurements. Stress due to noise, vibration or climatic factors, as well as muscular and some types of mental strain, are reflected by the PR.

The PR may be taken at rest:

pulse at rest, initial pulse rate: this is normally taken in field studies when sitting

pulse after work: this is the PR observed during work, less initial PR (= increase over initial PR)

recovery pulse rate: PR taken during recovery time minus initial PR.

In all these studies, it is essential to measure the PR of the test person within a certain period of time (10-15 minutes in most cases) before work and at full rest. The PR during work is used for assessing the dynamic workload. This rate should not exceed three beats above the initial PR while standing, 35 above it while sitting and 40 above it while lying down, on a daily average. Another assessment criterion is the sum total of recovery pulse rates. After a working phase a measurement is made of the time it takes before the test person reaches his initial PR. In general, the sum total of recovery rates should not exceed 100 beats.

#### 4.6 Fatigue and recovery

The cardiovascular system supplies the human organism and the skeletal muscles with oxygen. The more strenuous the work and the higher the energy input, the faster will be the rate of oxygen supply to the individual muscles. As a consequence, a larger volume of blood is transported in a given time; thus the number of heartbeats increases correspondingly. Once oxygen supply falls short of oxygen consumption, the organism lacks oxygen. This manifests itself physiologically as fatigue. The brochure Current Occupational Medicine gives the following definition: "Under a constant workload, exertion

parameters, such as the pulse rate, increase with time. The exertion level exceeding the defined maximum tolerance limit indicates the degree of fatigue, which ought to be counteracted by an interruption of work and breaks." Thus fatigue is defined both as a dynamic process (during work activities) and as a static state (immediately after stopping such activities).

Fatigue must be regarded as a reversible impairment of function. The process of restoring the full biological performance capacity through breaks is called recovery.

#### 4.6.1 Example of a recovery time study based on ergonomic tests

Study objective: determination of the required recovery time in felling coniferous trees with a power-saw (no debarking in the stand); one-man operation following a given work procedure

Execution of study: for a period of 69 days, PR measurements were taken on four forest workers (whole-day studies). Total volume: 809 m<sup>3</sup>, 633 trees. Average initial PR when sitting: 73 beats/minute.

Ergonomic bicycle tests were carried out each day before work started. With the aid of the mean regression curve it was calculated that forest workers were required to put in 90 watts of energy to perform the work assigned to them.

Evaluation of the data observed in the four test persons showed a performance of 90 watts, with an average PR of 105 beats/minute. The increase of 32 beats over the initial PR was thus below the minimum tolerance limit of 35 beats (105 - 73 = 32). To extrapolate these values for the entire work-force of the Austrian Federal Forest Enterprise, a base for comparison was established. For this purpose, circulatory function tests involving 200 forest workers selected at random throughout Austria (about 8 percent of the total work-force) were performed. With statistical calculation methods, the data were evaluated using regression equations.

Mean regression line

$$y'' = (\bar{y} - \bar{x} \frac{sy}{sx}) + \frac{sy}{sx} \cdot x$$

$$x'' = (\bar{x} - \bar{y} \frac{sx}{sy}) + \frac{sx}{sy} \cdot y$$

The data gave a PR of 113 at a performance level of 90 watts.

The computed average initial PR of the work-force amounted to 74 beats per minute; thus the increase of 39 beats was above the maximum tolerance level.

According to Hettinger, an excess of the maximum tolerance level by one value/point can be lowered by 2% if proper break allowances are made. In our case, an 8% allowance for breaks was made, in addition to the 22.3% recovery determined for the test individuals. Correspondingly, the recovery allowance totalled 30.3% of genuine working time.

For studies of this type, it is always necessary to use identical work procedures, tools and methods.

GENERAL SURVEY OF AVERAGE DAILY VALUES

	Mean tree diameter (cm) Ø				
	up to 19.9	up to 29.9	up to 39.9	over 40.0	total
<u>Genuine working time (GWT)</u>					
Minutes per m <sup>3</sup>	56.2	27.3	16.3	14.4	24.1
Total number of hours per day	5.1	4.3	4.5	4.4	4.5
<u>Machine time</u>					
Percentage of GWT	23.1	48.8	53.9	57.9	42.8
Number of hours worked with power-saw each day	1.2	2.1	2.4	2.5	1.9
Increase over initial PR when sitting, referred to GWT	42	41	42	47	42
<u>Allowance percentage (values refer to GWT)</u>					
Job-related allowance	3.4	5.6	8.5	8.9	6.1
Personal allowance	1.3	0.8	1.1	1.0	1.0
Job-related waiting time	1.0	3.8	4.5	2.0	2.9
Changeover time	2.2	2.2	2.7	3.2	2.5
Recovery time	20.8	24.1	20.7	23.4	22.3
<u>Total of allowances in %</u>	28.7	36.5	37.5	38.5	34.8
Hours of GWT + total of allowances: total working time (TWT)	6.5	5.8	6.2	6.0	6.1
Increase in PR over initial PR while sitting related to TWT	37	35	36	42	37
Share of down-time in TWT (due to weather, transport or equipment-related loss of time) in %	8.5	8.8	4.2	7.1	7.5
Share of lunch breaks in GWT in %	18.4	20.2	22.1	20.7	20.1
Thus total increase in GWT in %	55.6	65.5	63.8	66.3	62.4
Total number of hours per day (TOTAL)	7.9	7.0	7.4	7.3	7.4
Increases over initial PR while sitting referred to total	32	30	31	36	32
<u>Total of allowances in % (without lunch break)</u>	37.2	45.3	41.7	45.6	42.3
Hours without lunch break	7.0	6.2	6.4	6.4	6.5

#### 4.7 Ergonomic tests

To assure the comparability of PR examinations of different test individuals, various tests which have been successfully applied in sports medicine for some time are used. In these tests, ergonometric bicycles are used; evaluation is based on the finding that there is a relatively reliable correlation between exertion expressed in watts, PR, oxygen intake and arterial pressure.

##### 4.7.1 The ergonometric bicycle

The test person drives a disc, which is mechanically or electrically braked. Performance can be determined from braking force and the number of revolutions per minute. In physics, work is defined as performance within a time unit.

Performance	=	Work : time = mkg : sec
Work	=	Strength x distance = kp x m
1 mkg/sec	=	9.81 watts
75 mkg/sec	=	1 PS = 736 watts
1 watt	=	0.0013586 HP

The larger the braking force set on the ergonometric bicycle, the higher the performance of the test individual, provided that the number of revolutions per minute remains constant. Or, conversely, if the braking force is kept constant, the performance increases (the number of revolutions per minute increases).

##### 4.7.2 The pulse rate under load (according to E.A. Müller)

The sub-maximum tolerance test is based on the increase in the PR with accurately measured exertion on the ergonometric bicycle. In this test, the mean increase per minute in the PR is determined. The individual is exposed to a continuously growing load at a rate of 10 watts per minute. The mean increase is designated as PR under load. For well-trained strong males, this value should range between 1.8 and 2.8 beats per minute.

##### 4.7.3 Pulse working capacity

This load test is also based on the ergonometric bicycle. At a constant number of revolutions per minute, the load is increased (e.g. 50, 75 and 100 watts) every three minutes of pedalling. At the end of each minute, (that is, between the 50th and the 60th seconds) the PR is taken and plotted in a system of coordinates. For physiological reasons, the PR increases more or less parallel with the load. Thus, the watt performance can be calculated for an assumed PR of 170, for example. Before and after pedalling, the PR at rest is recorded.

The test individual's body weight is taken into account. Healthy men should be able to reach a performance level of 3 watts ( $\pm 0.5$  watts) and women 2.5 watts ( $\pm 0.5$  watts) for each kilogram of body weight; in this case, their circulatory function is within a statistically corroborated mean range.

## 5. ACCIDENT RESEARCH, ACCIDENT PREVENTION AND SAFETY AT WORK

In the past, accident prevention rules were the outcome of practical experience. With increasing mechanization and the introduction of new working procedures in forestry, guidelines and practical rules of behaviour have become necessary. Some countries have passed labour protection legislation, which has been applied in practice for some time.

Accident prevention aims not only at avoiding injuries and death, but also at reducing the burdens on individual enterprises and the economy as a whole resulting from incapacity to work, the payment of sickness benefits, and the costs for medical treatment and rehabilitation.

Examination of all cases where professional forest workers were injured reveals that 39% were injured in the legs, 30% in the hands, 17% in the head and 14% in the trunk. Thirty-eight percent of all accidents occurred at the landing, 33% during conversion and 18% during felling. These figures are taken from the investigations conducted jointly by the General Accident Insurance Company and the Social Insurance Company of Farmers in Austria in 1977. According to these investigations, in 1977, 5 209 work accidents occurred in which a total of 10 707 000 m<sup>3</sup> of timber was cut. Forty-two persons were killed and 5 167 injured. The study clearly illustrates that professional forest workers have far fewer accidents than farmers doing forest work as a sideline. This may be partly explained by their regular and better training, but also by the use of suitable protective equipment.

### 5.1 Causes of accidents

The following list of causes of accidents, their effects and remedies, is taken from a training and instruction brochure (Procedures and Organization in Wood Harvesting, published under the Austrian Cooperation Agreement between the Forest Industry and the Board and Paper Industry (FPP)).

#### 5.1.1 Felling

Source/type of accident Falls

Consequence: Injuries from cutting equipment and general injuries from falling

Remedy: Select safe walking and standing areas; carry equipment so that falling will not result in injuries. Wear close-fitting working clothes and safety shoes with solid, skid-proof soles. Use leg irons when walking on steep slopes, especially on frozen soil, and on debarked wood.

Source/type of accident Falling branches

Consequence: Injuries of all types, particularly to the head

Remedy: Constantly look out for danger spots; wear protective helmet.

Source/type of accident Starting power-saw

Consequence: Cuts

Remedy: Ensure proper starting position; use general protective equipment.

<u>Source/type of accident</u>	Second person within range of the power-saw
Consequence:	Cuts
Remedy:	No other person should be within a radius of 2 m of the operational range of the power-saw. Helpers must also wear adequate protective clothing.
<u>Source/type of accident</u>	Power-saw rebounds (kickback)
Consequence:	Injuries to all parts of the body
Remedy:	Hold grip-handle firmly, closing the fist. Support saw and keep it as close as possible to your body. Avoid cutting with the tip of the cutting blade and be prepared for the saw to jump back. Use proper cutting techniques, chain brake or hand protection, safety chain, protective gloves and leg protection.
<u>Source/type of accident</u>	Falling tree
Consequence:	Injuries to the cutter and other workers
Remedy:	Other persons should keep out of the felling range (1 1/2 to 2 tree lengths). Observe felling range immediately before bringing down the tree. Warning shout with power-saw switched off before felling. Determine a clear escape route beforehand: laterally to the slope, laterally on flat terrain, backward when the tree falls. Look upward. In conditions of poor visibility, discontinue felling operations.
<u>Source/type of accident</u>	Suspended trees brought down by felling another tree or by efforts to free the suspended tree itself
Consequence:	Serious injuries resulting from sliding or tilting tree or breaking tops. Severe or fatal injuries caused by sudden fall of the tree
Remedy:	Never execute this kind of operation.

#### 5.1.2 Skidder extraction

<u>Source/type of accident</u>	Skidder overturns during traverse of sloping terrain
Consequence:	Injuries to driver
Remedy:	Drive only on terrain which presents no threat to the skidder, taking into account its track width, centre of gravity and ground traction. Broader track width, addition of water in the tyres, nonskid chains, and lower height of ancillary equipment can improve skidder stability. Attach load at the lowest possible point. Use protective cab, safety belt, protective helmet. Hold on to the steering wheel when the skidder rolls over.



Source/type of accident Skidder overturns during lateral pulling of the load

Consequence: Injuries to driver

Remedy: Skidder should be moved into the direction of pulling, if possible. Cable should be as low as possible. Use protective cab, safety belt, protective helmet.

Source/type of accident Traction cable breaks

Consequence: Injuries to driver or helper

Remedy: Protective grid behind driver's seat. Safety friction clutch. Observe a safety factor of three as regards the traction cable. Repair damaged cables in time. Loads must be adjusted to the traction power, stuck loads must be freed with the cable lax.

Source/type of accident Running traction cable, cable inlet on the cable winch

Consequence: Especially hand injuries

Remedy: Never touch moving cables. Control winding up of cable only by moving it laterally with a lever. Use an automatic winding-up unit.

Source/type of accident Rolling or sliding timber

Consequence: Injuries to driver or helper

Remedy: Do not station skidder along lines of slope. Use protective cab.

### 5.1.3 Work-induced permanent damage

Source/type of damage Noise of machinery

Consequence: Impaired hearing, nervousness, circulatory disturbance with continuous exposure

Remedy: Try to alternate noisy work with quiet cycles. Use earmuffs, sound-insulated driver's cab.

Source/type of damage Vibrations of power-saw

Consequence: Vasoneurosis, damage to joints

Remedy: Vary work to include operations without power-saw. Use anti-vibration handle, protective gloves, heated handle.

Source/type of damage Vibrations and shaking of skidder during travel

Consequence: Damaged intervertebral discs and kidney damage

Remedy: Ergonomically designed driver's seat, kidney-protection belt, taking turns with other people.

<u>Source/type of damage</u>	Inadequate working clothes, no shelter
Consequence:	Rheumatism, common colds
Remedy:	Choice of working clothes appropriate to the season, shirt and pullover with extra-long back, dungarees, sweat-absorbing underwear, waterproof rainwear. Mobile hut for rest.
<u>Source/type of damage</u>	Wrong arrangement of breaks, leisure time and holidays; excessive daily working hours
Consequence:	Impairment of ability to concentrate, excessive physical strain
Remedy:	Maximum daily working time of eight hours. Arrangement of short breaks. Proper recovery during leisure time.



Audiometer used to detect hearing losses (Photo: T. Pasca)

TELEMETRIC MOBILE COMPUTER UNIT  
FOR ERGONOMIC MEASUREMENTS IN FOREST WORK

by

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Vienna, Austria

In view of the ever greater mechanization in wood harvesting operations, the need has arisen to draw up physiological profiles of work places to determine the stress to which people are exposed when operating forest machinery such as articulated wheeled skidders, log processors and conversion equipment. For this purpose a mobile telemetric unit is now used by the Research Institute to carry out surveys and research work on ergonomics in forest activities. This unit is capable of transmitting the operator's pulse rate to the receiver over long distances. In addition, the unit simplifies the data evaluation process because it is linked to a computer. The recent advances of space satellite technology have led to a considerable reduction in the size of electronic components required for the unit. Telemetry (the transmission of electrical data by wire or by radio) is increasingly used in the field of biology and medicine.

In principle, the telemetric equipment functions as follows: sensors monitor a physical process taking place in the observed object and transform this into a signal by means of a data conditioning module. In a multiplexer, which permits intermittent data retrieval, several data channels are modulated to one channel. The ultra-high frequency band is used primarily for the transmission of data from the transmitter to the receiver. The data are first demodulated and decoded and then fed into recording or visual display units for evaluation.

This type of mobile measuring, transmission and evaluation equipment has become an indispensable aid to occupational studies on, for example, flight, sports and traffic, as well as to cardiological rehabilitation. Mobile systems of this kind must be capable of recording, accurately and continuously, the physiological and physical parameters of freely moving patients and control persons. They offer the technological basis for long-term studies over distances of varying lengths, for simultaneous monitoring of several controls and for multifactorial recording of several parameters. They provide reliable data, which can be retrieved at any time.

The telemetric equipment described above was produced by Messerschmitt-Bölkow-Blohm GmbH (MBB), Munich, and is marketed under the name Monitel 2. The equipment is based on a frequency multiplexing system which permits the accurate transmission of data and which is reliable in operation. Twenty-seven separate high-frequency channels of the 433 MHz band are available for the wireless transmission of two parameters for synchronous monitoring.

The telemetry system consists of a small transmitter and a module type of receiver. Its compactness and low weight facilitate the mobile use of the transmitter, which imposes no physical strain on the test individual. The transmitter may be put into a pocket of working clothes, or attached to a belt or protective helmet. The pulse rate is measured by means of chest electrodes and the recording resembles an electrocardiogram.

The telemetric system Monitel 2 offers a wide range of applications going beyond pure ECG monitoring. When suitable transmitters and monitoring instruments are used, other parameters such as the respiratory rate and the skin surface temperature can be monitored and transmitted by radio. Depending on terrain conditions, the operator's biofunctions can be monitored over a range of several kilometres. A commercially available set of batteries permits continuous operation of the transmitter for eight to ten hours.

The receiver is a separate 19-inch unit. In addition to the oscilloscope, a number of other instruments may be linked to the telemetry system. Electrocardiographs, tape-recorders or analogous digital converters permit further monitoring and signal conversion.

The entire equipment is built into a Volkswagen bus and is therefore fully mobile. The Federal Institute of Agricultural Techniques at Wieselburg/Erlauf, Lower Austria, integrated the measuring, storage and evaluation equipment and designed the work place of the testing equipment in an exemplary way. Power is supplied by a petrol-engine-driven generator via accumulators and transformers producing 220 V alternating current. A telescoping antenna assures trouble-free reception within the operating range. A Digital Equipment computer, model PDP 11/03, system RT 11, serves as the evaluation unit. Using this computer, the ECG and the respiratory rate of a test individual can be transmitted via a dual-channel transmitter, and at the same time the work cycles observed by a work study expert can be transmitted by means of another, single-channel transmitter. Further expansion of the equipment is planned to monitor the biodata and time study results of four test persons simultaneously.

The electronic data-processing equipment offers a number of advantages for data acquisition and evaluation. The testing staff is relieved of extensive and time-consuming calculation work, human error is reduced to a minimum, the test results are obtained more rapidly and the information volume is enlarged. The automatic print-out assures a speedy calculation of test results; results are more easily reproducible, for comparison with standard values. In addition recording and filing of test results are automatic and data retrieval for statistical use is rapid.



Mobile telemetric computer unit built into VW minibus

(Photo: J. Wenc1)

ANNEX 1

COURSE PROGRAMME

Monday, 30 May	Arrival at Klagenfurt Airport (via Vienna Airport) Transfer by bus from Klagenfurt Airport to the Forestry Training Centre Ossiach Registration and information Accommodation in hotels and guest houses
Tuesday, 31 May	General information at the Information Desk in the Club Room of the Forestry Training Centre Ossiach  Official opening of the Training Course in the Rittersaal of the Stiftshotel Ossiach:  Welcoming speech and introduction to the Course by H. Redl, Head of the International Division, Federal Ministry of Agriculture and Forestry  Introductory speech by L.R. Letourneau, Director, Forest Industries Division, Forestry Department, FAO, Rome  Excursion to Ossiacher Tauern. Multiple functions of mountain forestry (A. Trzesniowski)  Key address by Dr. F. Eggl, Director-General of the Austrian Federal Forestry Enterprise  Reception in the Rittersaal of the Stiftshotel Ossiach
Wednesday, 1 June	Cooperation between FAO and Austria (H. Redl)  "Basic Principles for the Selection of Logging Equipment" (L.R. Letourneau)  "Logging Techniques in Austria" (A. Trzesniowski)  "Some Technical and Economic Aspects of Logging in Developing Countries" (R. Heinrich)  Demonstration of small size cable cranes in Ossiacher Tauern (A. Trzesniowski and staff)
Thursday, 2 June	Excursion to Gurk and Strassburg. Visit to the alpine road in Nockalm (D. Hannak-Hammerl, R. Heinrich, A. Trzesniowski)
Friday, 3 June	"Tree Felling in Mountainous Coniferous Forests, Techniques, Production and Costs" (A. Trzesniowski)  "Medium Technology in Wood Harvesting" (R. Heinrich)

Country reports

Demonstration of tree felling and wood extraction by wheeled tractors for the assortment , tree-length and full-tree methods (A. Trzesniowski and staff)

Saturday, 4 June

Visit to Villach, Klagenfurt and Dobratsch road (R. Heinrich, A. Trzesniowski)

Sunday, 5 June

No official programme  
(Church visit and concert in Ossiach)

Monday, 6 June

Country reports

"Logging Case Studies in Mountainous Forests" (A. Trzesniowski)

Demonstration of a logline and a gravity cable crane  
(A. Trzesniowski and staff)

Tuesday, 7 June

Excursion to Hespera-Döman, Wolfsberg

Demonstration of different logging methods and visit to the sawmill and computerized log sorting yard (H. Clavadetscher, W. Brabek, D. Hanak-Hammerl type, R. Heinrich, A. Trzesniowski)

Wednesday, 8 June

Country reports

"Organizational Forms in Wood Harvesting in Austria" (Self-employed, Contractors, Farmers, Worker and Machine Cooperatives)  
(A. Trzesniowski)

Demonstration of the mobile cable yarder Steyr KSK 16  
(A. Trzesniowski and staff)

Thursday, 9 June

Country reports

"Case Studies of Wooden and Concrete Check-Dams in Connexion with Forest Roads" (H. Hattinger)

Excursion in the area of Afritz.  
Viewing of torrent control protection works in relation to forest roads (H. Hattinger, F. Huna, R. Heinrich),  
A. Trzesniowski)

Friday, 10 June

Excursion to the Maltatal. Forest road construction in the high alpine region of Carinthia and the hydroelectric dam Kölnbreinsperre (H. Hattinger, R. Heinrich, A. Trzesniowski)

Saturday, 11 June

Evaluation of the first part of the course; drafting of conclusions and recommendations, final discussions and adoption of draft report. (R. Heinrich, A. Trzesniowski)

Farewell party at the Forestry Training Centre Ossiach.

Sunday, 12 June	Transfer by bus from the Forestry Training Centre Ossiach to the Forestry Training Centre Ort Itinerary: Ossiach - Bad Kleinkirchheim - Millstatt - Katschberg Kuchl (lunch) - Salzburg - Ort (R. Heinrich, R. Görtler)
Monday, 13 June	General information in the lecture hall of the training centre (R. Heinrich)  Welcoming speech by H. Redl, Head of the International Division, Federal Ministry of Agriculture and Forestry  Introductory speech "The Ort Forestry Training Centre and its History" (S. Stowasser)  "Forest Road-net Planning and Wood Harvesting" (R. Heinrich)  "Forestry Economy and Ecology with Special Emphasis on Logging in Mountainous Areas" (O. Sedlak)  Excursion to the federal forest district of Traunstein and to farmer's forests  Demonstration of examples of forest roadnets in rocky and soft soil areas (O. Sedlak, F. Auböck)
Tuesday, 14 June	"General Principles on Planning of Forest Roadnets" (O. Sedlak)  Country reports  Practical planning and layout of forest roads; demonstration of use of surveying instruments (O. Sedlak)
Wednesday, 15 June	Practical training; surveying and staking of the road alignment and additional necessary surveys for a forest road in steep terrain (O. Sedlak, R. Heinrich and staff of the Forestry Training Centre)
Thursday, 16 June	Elaboration of the forest road project from the survey data by the participants (O. Sedlak)  "General Introduction to Forest Road Construction Methods" (O. Sedlak)
Friday, 17 June	"Costs and Production in Forest Road Construction" (F. Auböck)
Saturday, 18 June	Excursion to Salzburg; sightseeing tour; return trip via St. Gilgen - Wolfgangsee - Bad Ischl - Ort (D. Hanak-Hammerl, R. Heinrich, W. Jirikowski)
Sunday, 19 June	No official programme (Church visit)

Excursion to the Abbey of Kremsmünster (D. Hanak-Hammerl,  
R. Heinrich, W. Jirikowski)

Monday, 20 June

"Road Embankment Stabilization with Biological and Engineering  
Works for Forest Roads" (R. Heinrich)

"Machine Input in Forest Road Construction with Special Emphasis  
on Rock Blasting in Mountainous Areas" (W. Blaha)

"Forest Road Planning, Location and Construction Techniques  
on Steep Terrain (O. Sedlak)

Demonstration of modern handtools for forestry (W. Jirikowski  
and staff)

Tuesday, 21 June

"Work Organization and Wood Harvesting Methods of the Austrian  
Federal Forest Enterprise" (W. Egger)

"Development of Wood Harvesting Techniques in Austria" (J. Wenc)

"Introduction to Ergonomics in Forest Operations" (J. Wenc)

Country reports

Tuesday, 22 June

"Methods for Time and Work Studies in Forestry" (J. Wenc)

Demonstration of and practice with instruments for ergonomic  
measurements applied in forestry work (J. Wenc and team)

Country reports

Practical exercises for different methods for time studies in  
tree felling (J. Wenc and team)

Thursday, 23 June

Introduction to an ergonomic checklist as a tool in forestry work.  
Group work (J. Wenc and team)

Demonstration of telemetric mobile computer unit for ergonomic  
measurements in forestry work (J. Wenc and team)

Country reports

Friday, 24 June

Case studies of work organization, time study and ergonomic  
measurements in tree felling and wood extraction (J. Wenc and team)

"Cost Calculations in Logging" (H. Jöbstel)

Evaluation of the course, drafting of conclusions and recommenda-  
tions, final discussions and adoption of the draft report  
(R. Heinrich, S. Stowasser)

Saturday, 25 June

Farewell speeches:

- H. Redl, Head of the International Division, Federal Ministry  
of Agriculture and Forestry

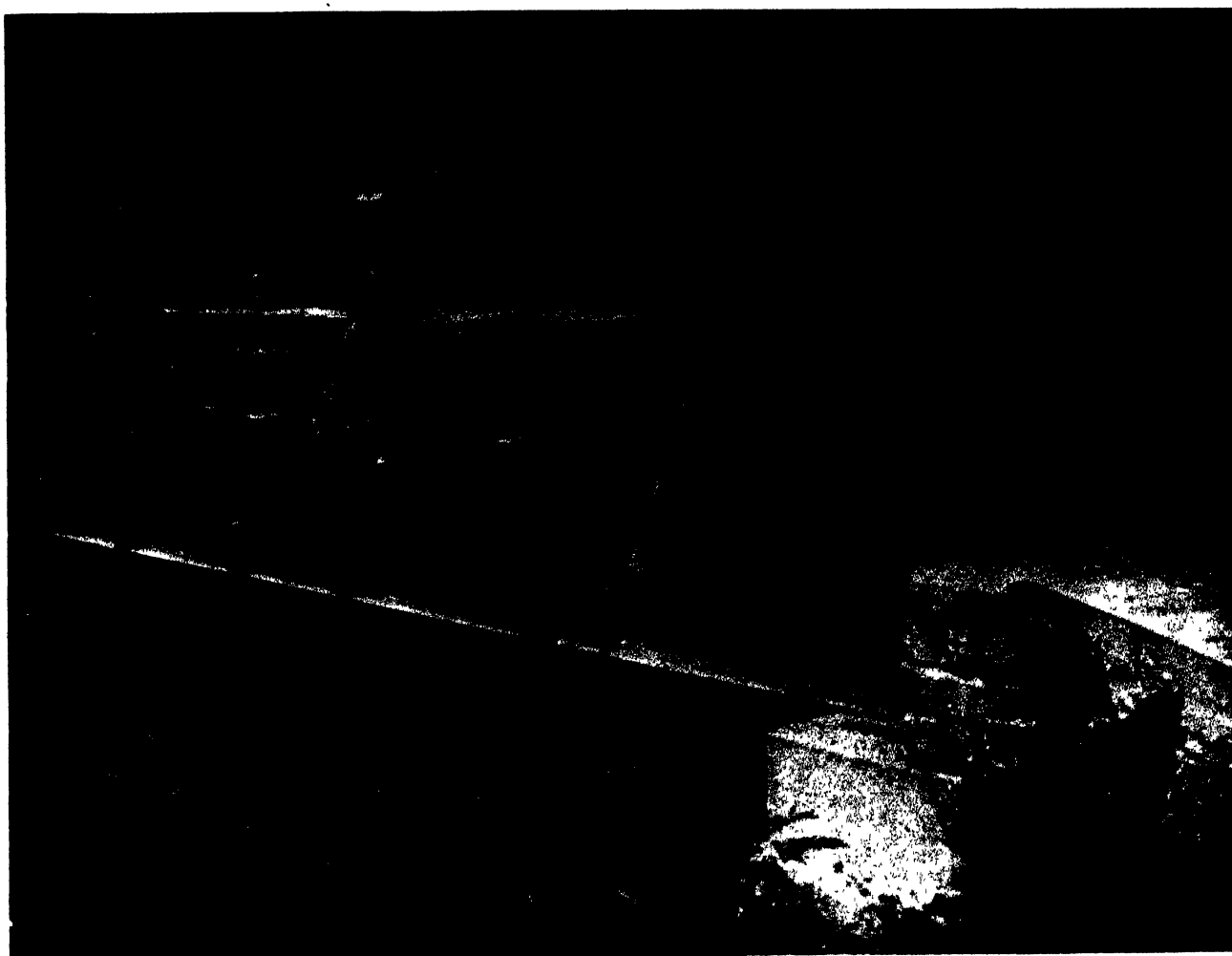


- E. Plattner, Head of Forestry Department, Federal Ministry of Agriculture and Forestry
- S. Stowasser, Director of the Forestry Training Centre Ort
- R. Heinrich, Forestry Department, FAO, Rome

Farewell party at the Forestry Training Centre Ort

Sunday, 26 June

Return trip by bus from Ort to Vienna Airport.



Adequate bridges to carry the heavy wheel loads as found on most forest roads are a necessary part of the forest road system

(Photo: R. Heinrich)



Downhill logging with Tricamat - 3-ton Carriage (skyline, mainline, haulback line and dropline). Drive station is an Urus mobile tower yarder. The carriage is passing an easily erected crossline intermediate support

(Photo: R. Hinteregger)

ANNEX II

LIST OF COURSE PARTICIPANTS

<u>Country</u>	<u>Name</u>	<u>Address</u>
BENIN	Agbahungba Georges	Forestry Research B.P. 06-707, Cotonou
BHUTAN	Pradhan Bhim Mani	Forest Directorate Office Thimphu
BHUTAN	Samba Pema	Director of Forests P.O. - Thimphu
BHUTAN	Wangdi Pema	Forest Directorate Office Thimphu
ETHIOPIA	Lisanework Demissie	Kef 16, Kebo 6 House No. 41
HONDURAS	Andino Roberto	Engineering Department (Cohdefor) Road Construction
HONDURAS	Murillo Reina Angel	Corfino, S.A., Corporación Forestal Industrial de Olancho, S. A. Tegucigalpa D.C.
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MEXICO	Luis de la Torre Augustin	Madero 215 NTE Durango DGO
MOZAMBIQUE	Chitará Sergio	Industrias Florestais de Manica Iflomakk
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NEPAL	Tuladhar Bikram Raj	Department of Forestry Babar Mahal, Kathmandu
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PARAGUAY	Berni Cesar	Faculty of Forestry, Nat. University of Asuncion
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SUDAN	Mubark Ahmed	Forest Administration Chief Enginwood Ind. Box 658, Khartoum
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TANZANIA	Tarimo Ndeliso	Logging & Road Project P.O. Box 7137, Arusha
TURKEY	Cakir Ramazan	Orman Isletmesi Müdürü Manisa
TURKEY	Sener Erol	Orman Gene , Müdürlüğü Ankara
UGANDA	Dutki Geo	Ministry of Agriculture and Forestry, Forest Department, P.O. Box 31, Entebbe
UGANDA	Odongo Matthew	Ministry of Agriculture and Forestry, Box 31 Entebbe
UGANDA	Turyatunga Frank Richard	Makerere University Dept. of Forestry, P.O. Box 7062 Kampala

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HANAK-HAMMERL Diether, Dipl.Ing. Oberrat	Bundesministerium für Land-u. Forstwirtschaft Abt. VA3, Stubenring 1 A - 1011 Wien
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(b) FAO Organizer

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